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National Aeronautics and Space Administration

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ECONOMIC ANALYSIS OF THE SPACE SHUTTLE SYSTEM

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for the

National Aeronautics and Space Administration
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Volume III

CHAPTER 7.0

THE POTENTIAL OF SPACE BUDGET AND THE IMPACT OF SPACE EXPENDITURE

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CHAPTER 7.0

THE POTENTIAL OF SPACE BUDGET AND THE IMPACT OF SPACE EXPENDITURE

7.1 Summary and Introduction

In the previous chapters we have discussed the benefit-cost analysis of alternative space transportation systems. The purpose of this chapter is to examine the relationship between the national economy and space activity. The results and conclusions of this chapter will contribute importantly to the overall economic framework within which the decisions of the Space Shuttle System will be made. These decisions have to make economic sense. The results of this chapter were, therefore, used to a major extent in Chapter 1 where the conclusions regarding the economics of the Space Shuttle System and alternative configurations are given.

Here we shall attempt to answer two major questions: first, how do the national economic conditions, among other factors, influence the level of space expenditure; and, second, what may be the impact of space expenditure on the various sectors of the economy, particularly in terms of production and employment.

With the dramatically successful Apollo Program approaching its completion, the nation must now formulate a new long-range space program as it is entering the new era of space exploration. To a large extent the formulation of such a long-range program must necessarily rely on our knowledge of the two-way relationship between the national economy in general and space activity in particular. Furthermore, whether a particular long-range space program can be successful depends largely on our ability to gain such knowledge and to apply it to obtain reliable forecasts of economic conditions and of space activity. It must be realized, however, that an economic analysis would naturally have certain limitations since it necessarily involves numerous simplifications. For example, domestic and international politics, though they are obviously important, usually do not enter an economic analysis explicitly. Despite these limitations, we hope to demonstrate that both the macro-econometric model and micro-activity analysis approaches can be expected to provide useful information for rational long-range planning of space exploration.

In an effort to determine the two-way relationship between national economy and space activity, both the macro-econometric model and the micro-activity analysis approaches have been employed. The terms "macro" and "micro" have been used here merely to indicate whether an analysis is being conducted at the national level or the industry level. We believe that while the influence of national economic conditions upon the level of space expenditure may be clearly discernable in a macro-econometric model, the spending impact of space expenditures on national economic conditions cannot be easily taken into account in such a model. The spending impact of space expenditures on various sectors of the economy, however, can be investigated by an alternative-activity analysis (or input-output analysis). For this reason, both the macro-econometric model and micro-activity analysis approaches have been applied.

A macro-econometric model has been formulated for the purpose of projecting both the national economy in general and space expenditure in particular. The possible influence of economic conditions on the level of space budget has been emphasized. Furthermore, we have also attempted to show how future economic conditions may be affected by different fiscal and monetary policies. By investigating the possible relationship between the level of space budget and economic conditions which to some extent may be affected by governmental fiscal and monetary policies, we hope to demonstrate that a suitably formulated macro-econometric model can be very useful for investment decision and long-range planning for various agencies of the Federal government, such as NASA.

The macro-econometric model employed in the present report is a dynamic system of twenty-eight equations, which include eight equations for the government sector dealing with both receipts and expenditures. In addition, the system of equations includes not only the relationships of production, consumption, and investment activities, but also the relationships of wage and interest determination and personal income, as well as corporate profit.

The econometric model with parameters estimated from annual observations of 1929-41 and 1947-64 was evaluated by comparing several alternative simulations with observed values for the period 1965-70 and was found to be reasonably satisfactory. In particular, the simulation results of the government sector were found to be significantly superior to those of the trend extrapolation of a more conventional single-equation model. Following the evaluation of the model, several alternative simulations were made for the period 1971-80. Both short-term and long-term projections as well as the implications of alternative-fiscal and monetary policies appear to be quite reasonable.

Finally, the alternative simulations for the period 1971-80, representing expansionary, neutral, and restrictive policies, respectively, were then used to project the future space expenditures. In order to achieve this purpose, we demonstrated that the level of current space expenditures may be explained not only by the level of past space expenditures, but also by the level of government spending in general, and other economic conditions such as the rate of inflation. Based on such an additional empirical relationship obtained from the annual observations of 1958-69, together with alternative simulations of the econometric model, several alternative projections of the level of space expenditures were provided for the period 1971-80. It is found that under the expansionary policy with relatively high rates of inflation, the projected level of space expenditures is in general lower than that of the alternative restrictive policy. According to the neutral policy, the level of space expenditures is projected to rise gradually from $3.3 billion in 1971 to $4.1 billion in 1980 (in terms of 1970 constant dollars). According to the expansionary and restrictive policies, the level of space expenditure is projected to rise from $3.5 and $3.2 billion in 1971 to $3.7 and $4.6 billion, respectively, in 1980 (again, in terms of 1970 constant dollars).

The purpose of our micro-activity analysis is to investigate the spending impact of space expenditures on various industries or groups of industries. Specifically, we attempted to evaluate the impact of the reallocation (and not simple elimination) of a $3 billion space expenditure on certain alternative uses in terms of the effects on the levels of production and employment. The alternative expenditures considered in this report include new construction, communication and transportation equipment, medical and educational services, as well as research and development in general.

The major source of our data is the most recent 1963 input-output tables of the United States, though the earlier 1958 input-output tables and the 1970 national income accounts were also used to obtain supplementary data. Basically, the classification of 1963 input-output tables, which divides all economic activities into 81 industries, has been followed in the present report.

The spending impact of a reallocation of $3 billion from space expenditures to each of the four alternative uses was found to be relatively small. There are two important economic conclusions: first, the New Space Transportation System and the particular Space Shuttle configuration have to be justified strictly within the context of benefit-cost, or cost-effectiveness analysis, and should not be justified by spending effects; second, the reallocation of funds from space to other activities can also not be justified by spending and employment effects only. The crucial test is: does the chosen Space Shuttle configuration stand the test of the social rate of discount. If yes, the Space Shuttle should be developed, based on the strength of its economic foundation.

Except for those industries which are directly affected by the reallocation of $3 billion, almost no other industry would be affected either beneficially or adversely by more than 1% of the 1970 production or employment levels.

As to the impact on the industries which would be directly affected by the hypothetical reallocation of $3 billion in space expenditures, while it is true that ordnance and aircraft industries together would decrease their production by nearly $4 billion annually, it must also be recognized that by spending the same funds in the alternative industry, the latter would increase its production by more than $3 billion. Yet, this reallocation of resources could not be done instantaneously, except at great cost not only to the aerospace industry, but also to industries where funding is suddenly increased by such inordinate amounts of funds. Thus, in the transition period the statement made in the context of long-term planning would need much more careful and detailed analysis.

Similarly, in terms of employment, while it is true that transportation equipment and ordnance industries would lose about 170 thousand man-years of employment annually, it must also be recognized that the alternative industry would gain in the long run more or less the same level of employment depending on its labor intensity.

In addition to the first and last sections which provide introduction and conclusions, respectively, this chapter is divided into two other sections, which discuss macro-econometric models and micro-activity analysis. In Section 7.2, dealing with macro-econometric models, a review of the approach, a description of the adopted model, and an evaluation of its application will be provided. To supplement this section, an appendix is presented to consider the possible modifications and the direction of further research. Section 7.3, a discussion of micro-activity analysis, follows essentially the same format as the previous section. In addition to a review of activity analysis, the adopted model will be described first followed by an evaluation of its applications. The material covered in this chapter is largely confined to a simple static input-output analysis. An effort has been made to investigate the feasibility of an application of dynamic input-output analysis. As a result, a new dynamic model has been developed. Since most of its empirical results are still very tentative and its discussion is very technical, such a dynamic model has been described separately in another appendix.

7.2 National Economy and Space Budget: Macro-Econometric Model Approach

7.2.1 Introductory

The major purpose of this section is to demonstrate that the macro-econometric model approach can provide a useful analytical technique for projecting the level of potential space expenditures in the future.[1]

Admittedly the level of space expenditures is not entirely determined by the state of the national economy. Other factors such as domestic and international politics often play a very important role in shaping the national policy of space exploration. Nevertheless, as we shall show later in this section, the effect of national economic conditions on the level of space expenditures in the past appears to be clearly discernable. For this reason, in order to obtain reasonable projections of the potential budget for space expenditures, it is necessary to develop a macro-econometric model for projections of national economic conditions. Some of the various indicators of economic conditions, such as the rate of inflation or unemployment as well as the level of government expenditures in general can then be projected, which in turn can then be used to project the potential budget for space expenditures in the future.

Although we recognize that the relationship between economic conditions and space activity is undoubtedly two-way in nature, only the question of how the state of the national economy can affect the level of space expenditures will be considered in this section. The other question regarding the economic impact of space expenditures on the state of the national economy or various sectors of the economy will be discussed in the next section.

The macro-econometric model adopted in this report has been formulated by expanding the revised Klein-Goldberger model [10] to include a sub-model of the government sector. The usefulness of such an econometric model has great potential. Not only the Federal government and its various agencies, but also state and local governments can all benefit from an econometric model which could be used to evaluate the consequences of alternative government policies and provide reasonable forecasts or projections of future economic conditions. In view of the increasing dependence of state and local governments on the federal grant-in-aid, and the recurrent proposals of some form of "revenue-sharing", it is clear that a rational long-range planning of even state and local governments may need a reasonably reliable forecast of the national economy. Equally evident is the fact that even various

Federal agencies such as the National Aeronautics and Space Administration cannot disregard the future of the national economy in their long-range planning, simply because their fundings are significantly affected by these future developments.

In addition to the introduction, this section is divided into six sections. Section 7.2 provides a brief review of various well-known econometric models for both short-term and long-term forecasting. Section 7.3 explains the adopted econometric model, which is a modification of the most recent Klein-Goldberger model. This includes the equations, the data, and the estimates of the parameters. Section 7.4 contains an evaluation of the model by comparing the results of dynamic simulations with the actual observations for the period 1965-70, and presents some results of short-term and long-term projections based on certain restrictive assumptions. Section 7.5 illustrates how an econometric model may be useful for projecting future expenditures for space research and technology. Finally, some qualifications and important findings are recapitulated in the concluding section, which also indicates the direction for further research.

7.2.2 A Review of Econometric Models

This section presents a very brief review of some of the relatively well-known econometric models. Furthermore, no attempt will be made to describe the specifications of particular models. [2] The purpose of the formulation of any econometric model ultimately aims at economic forecasting and policy analysis. One of the early devices of forecasting is based on the notion of "leading indicators". The models based on this concept, however, are not usually explicitly formulated. We shall, therefore, not concern ourselves with this type of model. In general, macro-econometric models are usually classified into annual models and quarterly models. While the earlier models are usually annual models consisting of relatively small numbers of equations, the more recent models are mostly quarterly models consisting of large numbers of equations. [3]

Perhaps the most familiar macro-econometric model is the Klein-Goldberger model of the United States originally published in 1955 [12], later described in [11] , and more recently revised in 1969 [10] . The revised Klein-Goldberger model, consisting of sixteen stochastic equations plus four identities, has been chosen as a basis in formulating the macro-econometric model adopted in the present report. A closely related but considerably expanded annual model, which has been estimated in first differences, is currently being used by the Research Center in Quantitative Economics at the University of Michigan. The predictive record of these and some other models has been evaluated by M. K. Evans in [5] . Generally speaking, the Klein-Goldberger model and many of its related models have emphasized the effective demand theory of J. M. Keynes, though Klein himself also considers macro-econometric models for developing countries [9]. Recently, the Office of Business Economics of the U. S. Department of Commerce engaged L. C. Thurow to develop an annual model which attempts to emphasize both supply and demand conditions [16]. The model consists of thirty-four equations, which are subdivided into supply equations, demand equations, income equations and identities. The model is designed to provide long-term projections of the U. S. economy and to aid in formulating economic policies. The emphasis, however, is on fiscal rather than monetary policies.

The Klein-Goldberger model has also been modified to several quarterly models. One of the best-known models is perhaps the Wharton School model of the Econometric and Forecasting Unit of the University of Pennsylvania. The model has been developed jointly by M. K. Evans and L. R. Klein. It is an outgrowth of two earlier quarterly models constructed by Evans and Klein separately. A complete description of this model can be found in Evans [5] . The properties of its time path have also been examined in detail in [5, Ch. 20] . One of the predecessors of the Wharton School model constructed by Klein was subsequently bequeathed to the Office of Business Economics of the U. S. Department of Commerce where it was modified and estimated with the revised data. This quarterly model is widely known as the OBE model [13] . While the purpose of this quarterly model is to provide short-term forecasts, the annual model developed by Thurow for the Office of Business Economics is intended for long-term projections. Therefore, the two models serve different purposes and can be used to complement each other.

There are so many other quarterly models that a complete discussion of them is clearly outside the scope of the present report. H. O. Stekler, in a recent article [15] , has evaluated six quarterly models of the United States, including the Klein quarterly model, the OBM model, and others. The most familiar quarterly models, besides the Wharton School model mentioned earlier, are perhaps the massive Brookings model and the Federal Reserve-MIT model. The Brookings model described in [3] and [4] , in a condensed version, consists of one hundred and eighty-two equations. Its solutions are presented by G. Fromm and Klein [6]. The model is also simulated for policy analysis by Fromm and Taubman [7] and used by Klein to evaluate the impact of the 1964 tax cut [8]. The Federal Reserve-MIT model was described in De Leeuw and E. Gramlich [2]. Through a detailed treatment of the financial market and its relation commodity market, the model attempts to offer an operational tool for an evaluation of the effect of monetary policy. Such an effect is found to be considerably larger than what is usually found in other econometric models.

7.2.3 Description of the Adopted Model

As was mentioned earlier, the revised Klein-Goldberger model as reported by L. R. Klein in [10] consists of sixteen stochastic equations and four identities.[4] This model was modified by including a sub-model of the government sector dealing with government receipts and expenditures. To keep the modifications minimal, we have introduced only six additional stochastic equations and two identities, making the modified Klein-Goldberger model a system of twenty-eight equations. By recent standards, this is by no means a large model. Many currently applied models now consist of fifty to one-hundred equations and some of the larger models consist of even more equations. For example, a full version of the Brookings model has more than three-hundred equations. On the other hand, some of the smaller models only consist of five to ten equations. The Chow model [1] is one of these smaller models which has been demonstrated to be quite adequate for many purposes. For our purpose of evaluating the impact of monetary and fiscal policies, the Klein-Goldberger model as modified should be an excellent base for further development. For convenience, we shall first provide a list of both endogenous and exogenous variables

B

and then present the entire system of equations together with the estimates of parameters to be used for dynamic simulation.

Endogenous Variables

C_d	consumption of durables, billions of 1954 dollars;
C_n	consumption of non-durables and services, billions of 1954 dollars;
R	residential construction, billions of 1954 dollars;
H	stock of inventories, billions of 1954 dollars;
I_m	imports, billions of 1954 dollars;
N_w	wage and salary workers, millions;
h	index of hours worked per week, 1954 = 1.00;
W	wages and salaries, including supplements, billions of 1954 dollars (compensation of employees);
w	annual earning, thousands of dollars;
r	average yield on corporate bonds (Moody's), percent;
S_c	corporate saving, including inventory valuation adjustment, billions of 1954 dollars;
P_c	corporate profits, including inventory valuation adjustment, billions of 1954 dollars;
π_r	rental income and net interest, billions of 1954 dollars;
I	investment in plant and equipment, billions of 1954 dollars;
D	capital consumption allowances, billions of current dollars;
r_s	yield on prime commercial paper, 4-6 months, percent;
X	gross national product, billions of 1954 dollars;
Y	disposable personal income, billions of 1954 dollars;
π	profits, including corporate profits and proprietor's income, billions of 1954 dollars;
p	implicit GNP deflator, 1954 = 1.00
T_p	personal tax and non-tax receipts, billions of current dollars;
T_c	corporate profits tax accruals, billions of current dollars;
T_i	reconciling item between net national product and national income, including indirect business tax, business transfer payments and statistical discrepancy, billions of current dollars;
T_s	contributions for social insurance, billions of current dollars;

G government expenditures for purchases of goods and services billions of 1954 dollars;

T_g government transfer payments and other expenditures, including net interest paid and subsidies, billions of current dollars;

T personal taxes plus contributions for social insurance less government and business transfer payments less interest on government debt, billions of current dollars;

S surplus (or deficit) of government receipts over expenditures, billions of current dollars.

Exogenous Variables

p_m implicit price deflator for imports, 1954 = 1.00;

W_g government wages and salaries, billions of 1954 dollars;

N_g government employees, millions;

N_s self-employed workers, millions;

N_L total labor force, millions;

$\sum_{i=1}^{20}[p\,(I+R)]_{-1}$ value of past 20 years investment, including plant and equipment and residential construction;

D_u dummy variable, 0 for 1929 - 41 and 1 for 1947 - 64;

r_d average discount rate at all Federal Reserve Banks, percent;

R_e year-end ratio of member banks' excess to required reserves;

E exports, billions of 1954 dollars;

IVA inventory valuation adjustment, billions of 1954 dollars;

T_b business transfer payments less government subsidies, billions of current dollars;

N_a number of aged persons over 65 years old, millions;

R_p personal tax rate computed as the ratio of personal tax to personal income;

R_c corporate profit tax rate computed as the ratio of corporate profit tax to corporate profits;

R_i indirect business tax rate computed as the ratio of indirect business tax to GNP;

R_s rate of contribution to social insurance computed as its ratio to personal income;

R_w per capita government compensation to employees computed by dividing compensation to employees by the number of government workers

R_g per capita government transfer payments computed by dividing government transfer payments by the number of unemployed and aged persons;

SD statistical discrepancy, billions of current dollars;

GPG government purchases of goods, billions of current dollars;

IS net interest paid plus government subsidies, billions of current dollars

Klein has provided four sets of alternative estimates for the parameters of the main model -- equations (1) through (20) -- using ordinary least squares, two-stage least squares with four and eight principles components, and full information maximum-likelihood estimation procedures respectively. The sample data are annual observations of 1929-41 and 1947-64. The national income data before the 1965 major revision were used in his estimation. For the sub-model of government sector -- equations (21) through (28) -- we have computed only one set of estimates using the ordinary least-squares procedure. The same sample periods, 1929-41 and 1947-64, are covered in this estimation. However, the national income data after the 1965 major revision were used. Although the revisions were quite substantial in a sense, in our judgment the discrepancy should not affect the performance of the model significantly.

Klein has concluded that among his four sets of estimates, the one based on the two-stage least-squares procedure with four principle components seems to provide the best simulation results. The estimated equations based on this set of estimates for the main model and the additional estimates for the sub-model of government sector, together with t - ratios and standard errors, are presented below. The subsequent discussion of simulation results will be based on this system of equations.

Consumption function (durable goods):

$$(1) \quad C_d - .7\,(C_d)_{-1} = \underset{(4.5)}{.231}\,(Y - .7\,Y_{-1}) - \underset{(1.0)}{.104}\,(C_d)_{-1} \underset{(3.7)}{-4.62}, \qquad S_e = 1.78$$

Consumption function (non-durable goods and services):

(2) $$C_n = \underset{(4.0)}{.250}\, Y + \underset{(8.9)}{.723}\, (C_n)_{-1} - \underset{(0.8)}{1.17}, \qquad S_e = 2.55$$

Investment function (residential construction):

(3) $$R = \underset{(5.6)}{.047}\, Y - \underset{(2.1)}{.46}\, r_{-1} + \underset{(3.8)}{.398}\, R_{-1} - \underset{(0.9)}{1.228}, \qquad S_e = 1.11$$

Investment function (inventories):

(4) $$H = \underset{(6.1)}{.134}\, (X - \Delta H) + \underset{(3.9)}{.405}\, H_{-1} - \underset{(5.7)}{24.3}, \qquad S_e = 2.39$$

Import demand function:

(5) $$I_m = \underset{(4.4)}{.033}\, X - \underset{(3.5)}{16.6}\, (p_m - p) + \underset{(2.1)}{.348}\, (I_m)_{-1} - \underset{(2.3)}{1.21}, \qquad S_e = 1.02$$

Production function:

(6) $$(X - W_g) - .95\, (X - W_g)_{-1} = \underset{(2.9)}{.334}\, (I + R)$$

$$+ \underset{(0.8)}{2.24} \left[(N_w - N_g + N_s) - .95\, (N_w - N_g + N_s)_{-1}\right]$$

$$+ \underset{(1.9)}{188.0}\, (h - .95\, h_{-1}) - \underset{(1.5)}{5.86}, \qquad S_e = 7.90$$

Hours worked function:

(7) $$h = -\underset{(2.5)}{.405}\, (w - w_{-1}) - \underset{(4.0)}{.0183}\, (N_L - N_w - N_s) + \underset{(27.3)}{1.14} \qquad S_e = .021$$

Labor demand function (wage share):

(8) $$W - W_g = \underset{(11.9)}{.496}\, (X - W_g) + \underset{(11.7)}{.131}\, (W - W_g)_{-1} - \underset{(8.7)}{12.5} \qquad S_e = 2.17$$

Wage rate determination equation:

(9) $$w - w_{-1} = \underset{(3.5)}{-.0218}\,(N_L - N_w - N_s) - \underset{(1.1)}{.679}\,(p - p_{-1}) + \underset{(5.1)}{.216}, \qquad S_s = .066$$

Interest rate structure equation:

(10) $$r = \underset{(3.0)}{.169}\, r_s + \underset{(12.0)}{.812}\, r_{-1} + \underset{(1.5)}{.402}, \qquad S_e = .357$$

Corporate saving function:

(11) $$pS_c = \underset{(25.1)}{.901}\,(p P_c - T_c) - \underset{(12.1)}{.889}\,(p P_c - T_c - p S_c)_{-1} + \underset{(0.1)}{.024}, \qquad S_e = .638$$

Non-corporate income equation:

(12) $$p\,(\pi - P_c) = \underset{(1.3)}{.010}\, pX + \underset{(11.3)}{.909}\,[p\,(\pi - P_c)]_{-1} + \underset{(0.7)}{.627}, \qquad S_e = 2.22$$

Rentier income equation:

(13) $$p\,\pi_r = \underset{(5.5)}{.075}\, p\,(I + R) - \underset{(1.9)}{1.08}\,(r - r_{-1}) + \underset{(26.9)}{.913}\,(p\,\pi_r)_{-1} - \underset{(2.0)}{.472} \qquad S_e = .615$$

Investment function (non-residential):

(14) $$I - .95\, I_{-1} = \underset{(4.2)}{.066}\,(X - W_g)_{-1} - \underset{(3.8)}{2.11}\, r_{-1} - \underset{(3.1)}{.590}\, I_{-1} + \underset{(3.1)}{9.329}, \qquad S_e = 2.54$$

Depreciation equation:

$$(15) \quad D = \underset{(39.4)}{.049} \sum_{i=1}^{20} [p(I+R)]_{-i} + \underset{(13.5)}{8.56}\, D_u - 1.411, \qquad S_e = 1.32$$

Interest rate determination:

$$(16) \quad r_s = \underset{(13.9)}{1.145}\, r_d - \underset{(2.4)}{.815}\, (R_e)_{-1} + \underset{(2.9)}{.533}\, D_u - \underset{(1.7)}{.511}, \qquad S_e = .370$$

Definition of real GNP:

$$(17) \quad X = C_d + C_n + R + (H - H_{-1}) + G + E - I_m$$

National income - National product identity:

$$(18) \quad p\,Y = p\,X - D - T_i - p\,S_c - T_c - T$$

Definition of profits (sum of proprietors' income and corporate profits):

$$(19) \quad p\,\pi = p\,X - D - T_i - p\,W - p\,\pi_r$$

Wage identity:

$$(20) \quad p\,W = w\,h\,N_w$$

Personal tax and non-tax receipts:

$$(21) \quad T_p = \underset{(21.15)}{.134}\, (p\,Y + T_p) + \underset{(1.40)}{30.59}\, R_p - \underset{(10.70)}{8.28}, \qquad S_e = 1.86$$

Corporate profits tax accruals:[5]

$$(22) \quad T_c = \underset{(76.43)}{.423}\, [p\,(P_c - IVA)] + \underset{(30.85)}{37.86}\, R_c - \underset{(28.14)}{15.75}, \qquad S_e = 0.20$$

Indirect business tax and non-tax accruals:

$$(23) \quad T_i - (T_b + SD) = \underset{(71.28)}{.091}\, p\,X + \underset{(7.64)}{129.50}\, R_i - \underset{(7.34)}{12.89}, \qquad S_e = 1.17$$

Contributions for social insurance:

$$(24) \qquad T_s = \underset{(7.72)}{.045}\,(pY + T_p) + \underset{(2.14)}{109.26}\,R_s - \underset{(6.09)}{4.53}, \qquad S_e = 2.06$$

Government purchases of goods and services:[6]

$$(25) \qquad pG - GPG = \underset{(4.88)}{1.55}\,N_g + \underset{(18.34)}{10.70}\,R_w - \underset{(8.82)}{15.48} \qquad S_e = 2.37$$

Government transfer payments and others:

$$(26) \qquad T_g - IS = \underset{(5.30)}{.633}\,[(N_L - N_w - N_s) + N_a] + \underset{(28.43)}{18.48}\,R_g$$

$$- \underset{(5.76)}{11.15}, \qquad S_e = 1.90$$

Personal transfer payments:

$$(27) \qquad T = (T_p + T_s) - (T_g + T_b)$$

Government surplus

$$(28) \qquad S = (T_i + T_c + T) - pG$$

Since the main model as developed by Klein and Goldberger has been discussed elsewhere [10], [11], and [12], we shall comment only briefly about the sub-model of the government sector which is newly introduced.

On the receipts side, personal tax (T_p) and contributions for social insurance (T_s) are determined by personal income ($pY + T_p$) and their respective effective tax rates (R_p and R_s). Corporate profit tax is determined by profits excluding inventory valuation adjustments [$p(P_c$-IVA)] and effective tax rate (R_c). Similarly, indirect business tax, excluding business transfer payments and subsidies as well as statistical discrepancy, is determined simply by GNP (pX) and effective tax rate (R_i).

On the expenditure side, compensation to employees (pG-GPG) is explained by the number of government workers (N_g) and their average wage rate (R_w), leaving government purchases of goods (GPG) as exogenous. Similarly, government transfer payments are explained by the number of unemployed and aged persons $[(N_L - N_w - N_s) + N_a]$ and average government transfer payments (R_g), leaving other government expenditures such as net interest paid and subsidies (IS) as exogenous.

7.2.4 Projection of the National Economy

In this section we hope to accomplish two tasks: first, to evaluate the performance of the adopted-econometric model by comparing its results of dynamic simulations with actual observations for the period 1965-70, and second, to provide several alternative projections for the period 1971-80. Both short-term and long-term projections will be presented.

We will begin with an evaluation of the adopted econometric model by considering the results of two dynamic simulations for the period 1965-70. In one simulation, the observed values of all exogenous variables were used, assuming that these variables can be forecasted precisely. In the other simulation the extrapolated values of all exogenous variables were used, employing the estimated relationships $E_t = \alpha E_{t-1} + \beta t + \gamma$ based on the data of the sample period 1947-64. These simulation results are shown as Simulations A and B, respectively, in Table 7.2.1 for 1965 and 1970.

While in deriving Simulation A the observed values of exogenous variables were required for each year in the forecasting period 1965-70, no observed values of any variable for the forecasting period were required to derive Simulation B. By comparing these two simulation results, one can obtain some idea about how the model can be expected to perform with and without forecasting errors in exogenous variables. A quick glance at Table 7.2.1 indicates that Simulation A, which uses observed values of exogenous variables, appears to be more accurate than Simulation B which uses extrapolated values of exogenous variables. The evidence is stronger for predicting five years ahead (1970) than for predicting only one year ahead (1965).

It must be pointed out that the simulations were started in 1965 for both Simulations A and B. For all subsequent years, the predicted values of

Table 7.2.1

Alternative Simulations for 1965 and 1970

Endogenous Variable	1965 Observation	1965 Simulation* (A)	1965 Simulation* (B)	1970 Observation	1970 Simulation* (A)	1970 Simulation* (B)
C_d	66.3	54.4	54.4	89.4	65.9	61.4
C_n	366.6	302.5	302.7	350.4	359.9	348.2
R	27.2	22.4	22.4	29.7	26.8	25.7
H	76.5	75.8	75.5	108.2	98.3	91.2
I_m	31.0	30.7	30.7	49.5	40.8	36.8
N_w	68.0	69.7	68.5	73.2**	79.8	72.6
h	.992	1.027	1.023	.951	1.063	1.022
W	318.4	313.8	311.7	398.5	378.5	353.3
w	4.683	5.619	5.570	6.227	7.172	6.451
r	4.64	4.90	4.82	7.36**	6.65	5.85
S_c	20.2	15.6	12.7	9.5	16.4	9.5
P_c	61.5	54.9	48.9	51.4	69.7	44.4
Π_r	29.3	32.5	33.2	37.3	36.0	39.8
I	57.6	46.9	46.9	68.2	49.2	49.6
D	59.8	58.2	58.2	84.3	74.3	74.3
r_s	4.38	4.63	4.20	7.83**	6.73	5.01
X	553.7	535.8	532.8	649.0	633.5	598.0
Y	372.6	366.0	367.0	455.0	438.5	415.9
Π	105.0	97.7	92.6	96.3	115.8	94.6
P	1.237	1.282	1.251	1.505	1.607	1.354
T_p	65.6	67.3	65.9	116.4	104.4	82.4
T_c	31.4	30.0	26.0	38.0	51.4	24.9
T_i	60.5	59.6	61.1	91.4	91.4	74.9
T_s	29.6	25.7	25.8	57.1	39.7	32.2
G	110.8	100.6	102.5	146.5	118.6	113.0
T_g	49.9	45.1	44.3	92.4	74.8	54.0
T	44.1	49.8	46.3	79.2	69.9	59.3
S	2.1	10.5	5.09	-9.6	22.1	6.3

* Simulation A uses observed values of exogeneous variables and Simulation B uses extrapolated values of exogeneous variables for the period 1965-1970.

** 1969 figures.

the previous year were used whenever lagged-endogenous variables were involved. The dynamic simulation of our econometric model really involves repetitive solutions of a system of non-linear equations. A Gauss-Seidel procedure has been adopted to obtain these solutions. For the particular normalization and ordering of our system of equations, each solution generally requires approximately 50 to 60 iterations to achieve convergence.

In order to gain some insight into the growth pattern of these dynamic simulations, the observed values and the predicted values of GNP (X), disposable personal income (Y) and corporate profits (P_c), all in billions of 1954 dollars, are presented in Table 7.2.2 together with the annual growth rates shown in the parentheses. These are key variables which affect government receipts as shown in equations (21) through (24).

While both Simulations A and B project a slowdown of real GNP growth rate, only the pattern of Simulation A may be regarded as close to the observed pattern. Unfortunately, it fails to predict a decline of real GNP in 1970. As to the projections of disposable personal income, while Simulation A reproduces the observed pattern reasonably well, the same cannot be said of Simulation B. The projections of corporate profits appear to be very difficult, neither Simulation A nor Simulation B can be considered satisfactory. This together with the rates of inflation and unemployment are probably the most difficult to predict. The present model is able to project continuous inflation for the period 1965-70, but not the situation of considerable unemployment which developed in 1970. The questionable results on employment may result from the failure to take technological progress appropriately into account in the production function. On the other hand, this may merely demonstrate the low-statistical reliability of the particular set of estimates that have been used for the production function shown as equation (6). Note that the t-ratio of the estimate associated with private employment $N_w - N_g + N_s$ is as low as 0.8. Note also that for this particular parameter the estimates given by other statistical procedures are 5.05 for OLS, 5.86 for TSL with 8 principal components, and 5.47 for FIML as compared with the given estimate of 2.24. All three alternative estimates are at least twice as large as the given estimate.

Table 7.2.2

Growth Pattern of Real GNP, Disposable Personal Income, and Corporate Profits, 1965-1970*

Endogenous Variable	Growth Pattern 1965	1966	1967	1968	1969	1970
GNP (X)						
Observation	553.7	590.0 (6.6)	604.6 (2.5)	633.7 (4.8)	651.3 (2.8)	649.0 (-0.5)
Simulation (A)	535.8	560.7 (4.7)	580.4 (3.5)	601.2 (3.6)	617.3 (2.7)	633.5 (2.6)
Simulation (B)	532.8	545.9 (2.5)	558.9 (2.4)	572.0 (2.3)	585.0 (2.3)	598.0 (2.2)
Disposable Personal Income (Y)						
Observation	372.6	402.8 (8.1)	416.1 (3.3)	433.1 (4.1)	441.7 (2.0)	455.0 (3.0)
Simulation (A)	366.0	384.6 (5.1)	396.7 (3.2)	411.0 (3.6)	423.2 (3.0)	438.5 (3.6)
Simulation (B)	367.0	377.9 (3.0)	387.7 (2.6)	397.2 (2.5)	406.6 (2.4)	415.9 (2.3)
Corporate Profits (P_c)						
Observation	61.5	64.8 (5.4)	59.9 (-7.6)	62.6 (4.5)	60.0 (-4.2)	51.4 (-4.3)
Simulation (A)	54.9	57.1 (4.0)	62.8 (10.0)	67.3 (7.2)	69.4 (3.1)	69.7 (0.4)
Simulation (B)	48.9	47.3 (-3.3)	46.3 (-2.1)	45.6 (-1.5)	45.0 (-1.3)	44.4 (-1.3)

* Figures in parentheses are annual growth rates.

Since one of our major interests is its applicability for projecting government receipts and expenditures, we may now consider the performance of the sub-model of the government sector in particular. For this purpose, Simulation A, previously explained for the period 1965-70, will be compared not only with observed values but also with the extrapolated values computed directly from the estimated relationships of $X_t = \alpha X_{t-1} \beta t + \gamma$ as have been done for the exogenous variables. These results are shown in Table 7.2.3.

There has been considerable skepticism, frequently with good justification, about the ability of a more complicated model to predict better than a simple model of trend extrapolation. It is at least comforting to find from Table 7.2.3 that our econometric model does indeed perform considerably better than the simple model of extrapolation if the exogenous variables can be predicted accurately. The superiority of the econometric model is much more substantial for longer-term predictions (1970) than for shorter-term predictions (1965).

In examining the projection of our econometric model, we shall consider both short-term and long-term projections. Specifically, we shall consider how under certain assumptions the model projects the economic conditions for the period 1971 through 1980. Although many different simulations have been performed, only two basic ones will be discussed in this section. The results of these two basic projections, referred to as Simulations C and D, for 1971 and 1980 are reported in Table 7.2.4. The projected values of all intermediate years, though they are available, are not included here.

In both simulations, the values of all exogenous variables for the period from 1971 to 1980 were extrapolated values based on the empirically estimated relationships $E_t = \alpha E_{t-1} + \beta t + \gamma$ computed from the sample data for the period 1947-1970 using the observed values for 1970 as initial values. While Simulations C was started in 1970, Simulation D was started in 1964. In Simulation C the observed values of endogenous variables for 1970 were used. In Simulation D, the observed values of endogenous variables for 1964 and the observed values of all exogenous variables for the period

Table 7.2.3

Government Receipts and Expenditures

1965 - 1970

(Billions of Current Dollars)

Government Receipts and Expenditure	Simulation and Extrapolation 1965	1966	1967	1968	1969	1970
Government Receipts						
Personal Tax (T_p)						
Observation	65.7	75.3	82.5	97.6	117.3	116.4
Simulation	67.3	73.7	82.1	90.4	97.3	104.4
Extrapolation	63.0	66.0	68.0	71.4	97.3	104.4
Corporate Profit Tax (T_c)						
Observation	31.3	54.7	56.5	40.6	42.7	38.0
Simulation	30.1	32.5	38.1	45.7	50.0	51.4
Extrapolation	27.9	28.4	29.0	29.7	30.5	31.2
Indirect Business Tax [$= T_i - (T_b + SD)$]						
Observation	62.5	65.3	69.6	78.1	85.2	92.0
Simulation	61.5	66.1	73.7	80.6	86.0	92.0
Extrapolation	62.0	65.7	69.5	73.4	77.5	81.7
Contributions for Social Insurance (T_s)						
Observation	29.6	38.0	42.5	47.1	53.6	57.1
Simulation	25.7	28.9	31.9	34.7	37.3	39.7
Extrapolation	29.9	31.8	33.8	35.7	37.7	39.7
Government Expenditures						
Government Purchases of Goods and Services (pG)						
Observation	137.0	156.2	179.9	202.2	212.1	220.5
Simulation	129.0	143.4	162.8	178.4	186.7	190.7
Extrapolation	134.1	139.6	145.2	150.7	156.2	161.8
Government Transfer Payments and Others (T_g)						
Observation	46.8	51.7	58.5	70.5	77.8	92.4
Simulation	45.1	49.4	54.3	60.4	66.6	74.8
Extrapolation	49.0	51.4	53.8	56.1	58.6	61.0

Table 7.2.4

Short-term and Long-term Projections for 1971 and 1980

Endogenous Variable	1970 Observation	Short-term Projection for 1971 Simulations (C)	(D)	Long-term Projection for 1980 Simulations (C)	(D)
C_d	59.4	73.1	68.4	102.1	96.4
C_n	350.4	377.6	371.7	532.8	503.2
R	19.8	26.3	27.6	40.6	38.2
H	108.2	112.3	101.8	151.6	139.7
I_m	49.5	41.0	42.4	62.3	63.8
N_w	73.2	77.4	81.2	107.6	105.4
h	.951	1.095	1.056	1.062	1.043
W	398.5	415.1	388.4	532.5	502.6
w	6.227	6.237	7.423	9.415	9.974
r	8.57	8.46	6.92	8.98	8.74
S_c	9.5	10.3	16.9	26.0	20.4
P_c	51.4	56.7	68.8	98.4	87.5
Π_r	37.3	46.0	37.5	50.0	48.4
I	68.2	53.6	50.0	61.1	56.7
D	84.3	77.5	77.5	107.5	107.5
r_s	7.72	6.52	6.52	8.32	8.32
X	649.0	696.3	647.7	873.7	821.3
Y	455.0	501.6	452.8	645.3	611.6
Π	96.3	112.3	116.7	159.8	147.5
p	1.505	1.274	1.640	2.021	2.181
T_p	116.4	94.3	110.3	197.8	202.4
T_c	38.0	32.9	50.4	86.4	83.1
T_i	91.4	79.0	94.9	157.9	160.3
T_s	57.1	36.5	41.9	73.5	75.0
G	146.5	151.2	117.4	122.0	113.0
T_g	92.4	86.3	83.4	217.1	218.6
T	82.5	45.4	69.2	57.2	61.9
S	-9.6	-35.4	21.9	55.0	58.8

1964-1970 were used. In fact, the essential difference lies in the selection of the values of all endogenous variables to be used for 1970; when dynamic simulations were made for the period 1971-1980 observed values were used in Simulation C, but simulated values were used in Simulation D for all 1970 endogenous variables.

<u>Short-term Projection for 1971</u>

We begin with a discussion of the results of short-term projections for 1971 as shown in Table 7.2.4. In order to derive GNP and disposable income in terms of current dollars, we simply multiply the simulated real GNP (X) and real disposable income (Y) by the GNP deflator (p). The resulting projected 1971 GNP and disposable income in current dollars are \$887 billion and \$1,062 billion respectively according to Simulations C and D. The projection of Simulation C is obviously unacceptable, and resulted largely from substantial under-estimation of the GNP deflator. The projection of Simulation D appears to be somewhat high, although it is slightly below the forecast of \$1,065 billion made by the Council of Economic Advisers.

The rate of inflation in our model is represented by the change of the GNP deflator (p). Simulation C projects no inflation (actually substantial deflation) and Simulation D projects only an inflation rate of 2.4% for 1971. This estimate appears to be too low. In principle, the rate of unemployment can be calculated from $[N_L - (N_s+N_w)] / N_L$, where only N_w is an endogenous variable. Unfortunately, both simulations resulted in an employment (N_s+N_w) which is greater than the labor force (N_L).

Consumption of both durable goods (C_d) and non-durable goods (C_n) is projected to grow at a rate of 3% to 4% in 1971, with the projection of durable goods consumption much more uncertain. Investments in residential construction (R) are projected to increase quite considerably because of the low level of 1970. Inventory change (H) is projected to grow at 3% to 4% annually. The simulated results for imports of foreign goods seem to be too low. Similarly, the model seems to underestimate considerably the levels of investment in plants and equipment (I) as well as depreciation (D).

Unfortunately, the projections of government receipts and expenditures without some adjustments in prediction errors are not very satisfactory. If we assume that the prediction errors in 1970 will persist in 1971 and adjust our projections accordingly, we find the resulting projections to be much more reasonable. On this basis, we find that government receipts from personal taxes (T_p), indirect business taxes (T_i), and social security taxes (T_s) may be expected to increase in 1971. Corporate profit taxes (T_c), however, are projected to decline slightly. Government purchases of goods and services, in 1954 constant dollars, (G) for 1971 are projected to remain at the 1970 level. In terms of current dollars, these expenditures (pG) are projected to increase slightly from $221 billion in 1970 to $224 billion in 1971. Government transfer payments (T_g), which also include subsidies and interest paid, are projected to grow from $92 billion in 1970 to $101 billion in 1971.

Long-Term Projection for 1980

The results of the long-term projection for 1980 as shown in Table 7.2.4 generally reflect a pattern of steady growth, with consumption (C_d and C_n) and investment (I, R and $H-H_{-1}$) increasing steadily, and government purchases (G) and imports (I_m) fluctuating somewhat. The projected GNP in 1954 constant dollars (X) for 1980 are $874 billion and $821 billion according to Simulations C and D respectively, representing an annual growth rate of approximately 3% or slightly lower. In terms of constant dollars, with the projected rate of inflation, the projected GNP for 1980 is $1,776 billion and $1,791 billion according to Simulations C and D respectively, representing an annual growth rate of approximately 6% or slightly higher.

The projected rate of inflation as reflected in the change of the GNP deflator has an average of about 3% to 4%. The employment and unemployment situation cannot be projected with great confidence by the present model. Nevertheless, both Simulations C and D clearly show that the employment of wage and salary workers (N_w) may be expected to increase from 73 million persons in 1970 to approximately 105 to 110 million persons in 1980, reflecting an annual growth rate of approximately 3.5% to 4%. This will perhaps be accompanied by a continuous decrease in the number of self-employed persons.

During the period 1970-80, consumption of durable goods (C_d) is expected to grow at an annual rate of approximately 5% to 5.5%. At the same time, consumption of non-durable goods (C_n) is expected to grow at a slightly lower annual rate of approximately 4%. Residential construction

(R) is projected to proceed at an even higher annual growth rate of approximately 7%. While inventory change (H) and depreciation (D) are expected to increase continuously, the level of investment in plants and equipment (I) is not projected to increase.

Government receipts and expenditures (expressed in current dollars) are projected to increase continuously over the period 1970-80. Government receipts from personal taxes (T_p) are projected to reach \$200 billion in 1980, representing an annual increase of approximately 5.5%. Corporate profit taxes (T_c), indirect business taxes (T_i), and social security taxes (T_s) are projected to reach approximately \$85 billion, \$160 billion, and \$75 billion respectively in 1980. Government expenditures are also projected to increase continuously, with government purchases of goods and services (pG) increasing at a slower rate than government transfer payments (T_g), which also includes subsidies and interest paid. Government purchases of goods and services (pG) are projected to reach \$245 billion, though in terms of constant dollars they are projected to decline. Government transfer payments are projected to exceed \$215 billion in 1980, more than doubling the level of 1970.

7.2.5 The Potential of Space Expenditure

In both simulations of the previous section, the values of all exogenous variables for the period 1971-80 were extrapolated values strictly based on empirically-estimated relationships. In view of the fact that future monetary and fiscal policies may be modified by various government agencies, it is desirable to examine how economic conditions may be affected by various policy changes. For the purposes of this analysis, we shall designate the previous Simulation D as representing the "neutral policy" and use its simulation results as a basis for comparison with some other simulation results of alternative policies.

Our experience with several simulations has indicated that the impact of each of the policy variables, separately, is not likely to be very significant. We shall, therefore, in addition to the simulation results of the neutral policy, report only two alternative policies, which will be referred to as the "expansionary policy" and the "restrictive policy" respectively. More specifically, the expansionary policy involves the reduction of discount rate (r_d), excess reserve rate (R_e) and all effective tax rates (R_p, R_c, R_i and R_s), and the increase of compensation to employees (R_w), government transfer payments (R_g), government purchases of goods (GPG), and interest and subsidies (IS), each by 10% from the level of the neutral policy for every year during the period 1971-80. The restrictive policy involves similar changes in the opposite directions. The results of long-term projections for 1975 and 1980 representing each of these three alternative policy simulations are reported in Table 7.2.5. While the neutral policy is represented by Simulation D, the expansionary and restrictive policies are represented by Simulations E and F respectively. It is apparent that the impacts of alternative government policies, though they are discernable, are not very drastic. For example, the levels of real GNP (X) in 1980 for the expansionary and the restrictive policies are higher and lower than that of the neutral policy by less than 2%; and the levels of government purchases of goods and services (G) for the expansionary and the restrictive policies are higher and lower than that of the neutral policy by less than 3%. It appears, therefore, that the economy is not likely to deviate considerably from the growth pattern indicated by the simulation results based on the neutral policy.

The great potential of the usefulness of an econometric model is evident. How such an econometric model can also be helpful to state and local governments or various government agencies in charge of some particular functions is perhaps less obvious. For this reason, it may be useful to consider how the model just discussed would also be of some value to a federal agency such as the National Aeronautics and Space Administration. Clearly, sometimes it would be desirable to modify the model for a particular application. For example, we may separate government purchases of goods and services into federal and state and local. Similar treatments can be applied to other expenditure and receipt items. For the moment, we shall refrain from these modifications and illustrate that the model, even as it now stands, can be helpful in projecting government expenditures for space research and technology.

Table 7.2.5

Long-Term Projections for 1975 and 1980 in Policy Simulations*

Endogenous Variable	Projections for 1975 Simulations			Projections for 1980 Simulations		
	(D)	(E)	(F)	(D)	(E)	(F)
C_d	79.4	80.6	78.1	96.4	98.5	94.1
C_n	424.9	428.8	421.0	503.2	511.4	494.7
R	31.7	32.4	31.0	38.2	39.5	36.9
H	117.1	118.9	115.1	139.7	142.6	136.7
I_m	51.2	54.2	48.2	63.8	68.0	59.5
N_w	89.8	91.6	87.9	105.4	107.1	103.6
h	1.048	1.063	1.033	1.043	1.057	1.028
W	434.3	439.4	429.0	502.6	510.3	494.5
w	8.541	8.824	8.245	9.974	10.470	9.449
r	7.73	7.33	8.13	8.74	8.14	9.34
Sc	17.0	21.0	12.5	20.4	23.2	17.3
Pc	74.1	82.1	65.2	87.5	95.4	78.4
Π_r	42.3	41.8	42.8	48.4	49.2	47.7
I	52.0	53.9	50.2	56.7	59.8	53.6
D	90.8	90.8	90.8	107.5	107.5	107.5
r_0	6.96	6.47	7.90	8.32	7.49	9.15
X	698.6	726.1	707.7	821.3	835.0	807.0
Y	499.0	522.2	508.9	611.6	623.2	599.4
Π	124.2	134.1	119.9	147.5	155.0	139.2
P	1.794	1.956	1.746	2.181	2.322	2.035
T_p	134.1	153.2	133.7	202.4	219.3	185.3
T_c	57.1	68.6	52.0	83.1	94.6	71.4
T_i	112.1	125.9	111.6	160.3	172.4	148.0
T_0	50.7	56.6	51.5	75.0	79.9	70.1
G	116.0	119.8	111.2	113.0	116.1	109.8
T_g	114.9	139.2	116.4	218.6	239.0	198.2
T	71.6	72.5	70.8	61.9	63.3	60.3
S	32.7	32.7	40.3	58.8	60.8	56.2

* Simulation D represents the "neutral" policy, and Simulations E and F represent the "expansionary" and "restrictive" policies respectively.

The successful Apollo Program which took man to the Moon is near its completion. The National Aeronautics and Space Administration is currently facing the important problem of formulating a new long-term plan. Since the available fundings for future projects are likely to vary, and sometimes fluctuate considerably, from year to year, the formulation of a rational long-term plan must be based on some knowledge of future funding. Forecasting the available fundings is therefore a very important task for decision-making.

Expenditures for space research and technology increased from merely $30 million in 1958 to the peak of $5,947 million in 1966, then decreased to $3,573 million in 1970. Explaining such an expenditure pattern is a complicated problem. It is, however, essential in forecasting to attempt to establish an estimated relationship from past observations. To explain the expenditures for space research and technology, we may hypothesize that the expenditure of a given year is determined by the level of government purchases of goods and services, general conditions of the economy such as the rate of inflation, and the expenditure in the last year for space research and technology. A good statistical relationship has been obtained to support such a hypothesis, using the data of sample period 1958-69. Denoting the expenditures for space research and technology as B (budget), government purchases of goods and services as pG (where p stands for GNP deflator) and $P_r = 100 \times [(p/p_{-1}) - 1]$ as the rate of inflation, we have

$$B = .008\,pG - .757P_r + 1.006B + .942,$$
$$(.627) \qquad (2.415) \qquad (6.923) \quad (.975) \qquad S_e = .550$$

The above-estimated equation was obtained by OLS with an R-square of .94 and a Durbin-Watson statistic of 1.75.

The usefulness of such a relationship depends greatly on the accuracy of the predictions of G and p. The values of these two variables, as we have seen before, turn out to be very difficult to forecast. Assuming that the projected values of these two variables, as provided by our long-term dynamic simulation, are reasonably reliable we may use them to project the expenditures for space research and technology in the next ten years. The necessary simulation results obtained from Simulations D, E and F for projecting space expenditures are given in Table 7.2.6, and designated as Projections I, II and III. The projections of space expenditures under alternative simulation policies are presented in Table 7.2.7. In this table, the projections actually begin in 1973, since budget figures were shown for 1971 and 1972.

Table 7.2.6 is largely self-explanatory. We may note, however, that throughout the entire period the levels of government purchases of goods and services under the expansionary and the restrictive policies are approximately $20 billion higher and lower than that under the neutral policy for the same year. The projected rates of inflation are mostly between 2.5% and 3.5%, except under the expansionary and the restrictive policies for 1971. The results of Table 7.2.7 are of some interest: the levels of space expenditures are higher for the restrictive policy than for the expansionary policy. This result is due to the fact that our forecasting equation for space expenditures depends much more on the inflation rate than on government purchases of goods and services.

Finally, the estimated equation used above in projecting space expenditures is by no means the only plausible formulation. For the purpose of projecting space expenditures, it may be desirable to separate federal purchases of goods and services, since space expenditures are funded exclusively through the federal government. Furthermore, the rate of inflation may not be the only relevant variable other than the levels of expenditures. There is some indication that the rate of unemployment also affects space expenditures, but the evidence is not very strong.

7.2.6 Concluding Remarks

In the previous discussion, we have described how the well-known Klein-Goldberger model can be modified to incorporate a sub-model for the government sector. The modified model has been tested empirically by examining its simulation results for the period 1965-70. We have found that employment, inflation and corporate profits remain as the major difficult problems which were not treated as satisfactorily as we may wish.

Table 7.2.6

Alternative Projections of Government Purchases and Inflation Rate*

Year	Government Purchases pG (billions) (I)	(II)	(III)	Inflation Rate Pr (percent) (I)	(II)	(III)
1971	$192.6	$210.7	$174.4	2.43	6.68	-1.94
72	196.9	215.4	178.3	2.86	3.22	2.42
73	202.2	221.2	183.0	3.08	3.46	2.61
74	208.1	227.7	188.5	3.16	3.56	2.79
75	214.2	234.4	194.1	3.23	3.55	2.95
76	220.6	241.2	199.9	3.29	3.48	2.98
77	227.0	248.3	205.7	3.29	3.56	3.06
78	233.5	255.1	211.6	3.34	3.44	3.13
79	240.4	262.5	217.6	3.33	3.51	3.19
80	246.5	269.6	223.4	3.36	3.48	3.20

* Projections I, II, and III correspond to Simulations D, E. and F, representing the "neutral", "expansionary", and "restrictive" policies respectively.

Table 7.2.7

Alternative Projections of Space Expenditures*

(Billions of Dollars)

Year	Projections of Space Expenditures: Annual Current Dollar Projections (I)	(II)	(III)	1970 Constant Dollar Projections (I)	(II)	(III)
1971	$3.40	$3.40	$3.40	$3.32	$3.47	$3.19
72	3.20	3.20	3.20	3.04	3.20	2.91
73	3.47	3.31	3.65	3.19	2.91	3.54
74	3.71	3.40	4.01	3.31	2.88	3.78
75	3.94	3.55	4.30	3.40	2.91	3.94
76	4.18	3.81	4.61	3.50	3.02	4.11
77	4.47	4.06	4.91	3.62	3.10	4.23
78	4.78	4.47	5.20	3.75	3.30	4.37
79	5.15	4.88	5.50	3.91	3.48	4.58
80	5.55	5.37	5.84	4.08	3.70	4.60

* Figures for 1971 and 1972 are budget figures (New York Times, January 30, 1971, p. 13). Projections I, II, and III correspond to Simulations D, E, and F, representing the "neutral", "expansionary", and "restrictive" policies respectively.

The employment situation in our model is largely determined by the production function (6) which may require some modification to take technological progress into account more appropriately. The problem of inflation is handled in a very complicated manner, as it should be. Nowhere is the amount of money supply treated explicitly in our model, except perhaps through the discount rate of Federal Reserve Banks (r_d). Whether the problem of inflation can be dealt with more satisfactorily by considering the money supply explicitly remains to be examined. As to the problem of corporate profits, it may be desirable to relate it to consumption and investment more closely rather than simply treating it as a residual, as implied in (12) and (20).

With these qualifications in mind, we have applied the model to project the economy for the period 1971-80, under certain restrictive assumptions. The results of two basic simulations for short-term and long-term projections have been discussed. Furthermore, the impacts of alternative governmental policies, both expansionary and restrictive, were also examined. These results have also been used to project future expenditures for space research and technology. The resulting patterns of our dynamic simulations of the national economy, in general, and space expenditures in particular, are not implausible. Our main purpose here, however, is to demonstrate that a carefully-constructed econometric model can be useful for decision-making not only at the national level but also at lower level federal agencies, or state and local governments. We have found that the expenditures for space research and technology are perhaps determined not so much by the level of government expenditures, in general, as by the rate of inflation and its own past-year level of expenditures. Therefore, in order to project the expenditures for space research and technology, we must be able to project not only the level of government expenditures, in general, but also the rate of inflation and possibly some other economic or even social indicators.

7.3.0 Space Expenditure and Industrial Activities: Micro-Activity Analysis Approach

7.3.1 Introductory

In the last section, we demonstrated how past levels of space expenditures have been affected by the development of the national economy, particularly with regard to inflation and employment situations. We then argued that any adequate forecast of space expenditures must take future economic conditions into account. Although these future economic conditions cannot be forecasted precisely, reasonable forecasts can be generated by an econometric model. We have already constructed an econometric model which serves not only the purpose of forecasting space expenditures, but also a wide range of many other purposes, including the forecasting of various government expenditures and the evaluation of the impact of fiscal and monetary policies, etc. The spending impact (or feedback) of space expenditures on the national economy was, however, not explicitly considered in such an econometric model. This omission is justifiable because the spending impact of space expenditures is likely to be quite negligible at the highly aggregate level, even though certain sectors of the economy may be affected very considerably.

The purpose of this section is to investigate the spending impact of space expenditures at a somewhat less aggregative industry level by adopting the approach of input-output analysis pioneered by W. Leontief [7] and [9], and many others [4] and [13]. Specifically, we shall attempt to evaluate the impact of the hypothetical reallocation (not simply the elimination) of $3 billion in space expenditures in terms of the production (or output, or sale) level and the employment level. The alternative uses of $3 billion in government funds considered here include new construction, communication and transportation equipment, medical and educational services, as well as research and development in general. The plan of this section is as follows:

In Section 7.3.2, we provide a brief review of activity analysis. In Section 7.3.3 the adopted simple-open-static model of input-output analysis is described briefly. In Sections 7.3.4 and 7.3.5, we examine the economic impact of the reallocation of a $3 billion space expenditure in terms of the levels of production and employment, respectively. Specifically, we do <u>not</u> deal here with the effects that programs of advanced technology, like the Space Shuttle System, have on the long-term competitive position of the United States' economy, or U. S. technology in the production of goods and services (including defense), and we do not look at the foregone benefits. For this, the results in Chapter 1 are relevant. This section does demonstrate that spending effects and employment effects are, in long-term national planning, neither an argument for or against the Space Shuttle development. Finally, the last section presents concluding remarks.

7.3.2 A Review of Activity Analysis

In a broad sense, the term "activity analysis" includes two somewhat separate yet closely related special branches of economic analysis: input-output analysis and linear programming. The distinction between input-output analysis and linear programming lies mainly in whether the process of choice or optimization has been explicitly examined, aside from the fact that the former is a subject-oriented economic exercise and the latter is a technique-oriented mathematical tool. Both input-output analysis and linear programming are closely related to general equilibrium and can be formulated in either a static or a dynamic framework.[1] In cases where either input-output analysis or a linear-programming problem is formulated in a dynamic framework, it becomes very closely related to the theory of economic growth. In general, the former tends to emphasize empirical applications, while the latter tends to stress theoretical investigations.

In a narrow sense, the term "activity analysis" has been used to refer to the application of linear-programming methods to general equilibrium theory [1]. We have chosen, however, to adopt the broader interpretation since the term "activity analysis", in its narrower sense, refers merely to an extension of input-output analysis by introducing linear-programming methods. In fact, we have used "activity analysis" mainly to indicate input-output analysis, since no explicit consideration has been given to linear programming and the optimizing process. Therefore, according to our usage, "activity analysis" and "input-output analysis" are almost synonymous, except that the former may include consumption activities in its analysis while the latter usually does not. For this reason, the term "activity analysis" seems to be preferable to "input-output analysis" when both production and consumption activities are investigated.

In the present report, except in one appendix, our activity analysis refers only to production activity. Therefore, activity analysis and input-output analysis are practically synonymous. The term "input-output analysis" may be defined as an analytical approach which attempts to take account of general equilibrium phenomena in the empirical analysis of production [1, p. 479]. Theoretical explorations began more than two centuries ago in the works of F. Onesnay (1766) and L. Walras (1874). Empirical investigations started much later with W. Leontief's (1936) study of the economic system of the United States [6]. A very concise exposition of the essence of input-output analysis is provided by R. Bharadwaj and P. H. Mathur [2]. Leontief himself, who pioneered and popularized the approach, described input-output analysis in simple nontechnical language in [8]. His early important contributions include [7], [9], and [10], dealing with a wide range of applications. More advanced materials of input-output analysis may be found in [4] and [12].

In general, an input-output analysis can be based either on "open" or "closed" models. In an open model the final demand sector which includes consumption and capital formation is taken to be given exogenously. While in an open model usually no attempt is made to explain the final demand sector, in a closed model it is considered endogenously sometimes by treating labor as a produced commodity and consumption as raw materials used up in the production of labor. This type of model, of course, is not the only kind of closed model. It, nevertheless, is the most familiar one.

An input-output analysis can also be classified into either "static" or "dynamic" models. According to the usual usage, a static model deals only with the analysis of equilibrium positions. The passage of time and the process of adjustment are not considered in this type of model. A dynamic model, on the other hand, considers these problems explicitly. Its analysis necessarily involves more than one time period, since it attempts to take account of the interrelationship of current and past outputs.

The simplest input-output analysis among all different models is an open-static model which treats consumption and capital formation as exogenous and involves only one time period in its analysis. Despite its various simplifying assumptions, such as no joint production and one given production technology with constant return to scale, it has been applied to many empirical analyses with some satisfactory results. Our analysis of the impact of space expenditures will also be based on such a simple model, though in an appendix we shall develop a closed-dynamic model which may also be applied to carry out a similar analysis. The empirical results of such an analysis are not reported here, since our preliminary results so far obtained are very tentative and require further verification.

7.3.3 Description of the Adopted Model

The model adopted in the following analysis of the spending impact of a reallocation of space expenditures on the levels of production and employment is an extremely simple one. Briefly, the model is an open-static model which consists merely of a system of linear equations, representing the production functions of various industries in the entire economy. In symbols it may be written as: (1) $(I-A)\ X = Y$ and thus (2) $X = (I-A)^{-1}Y$ where I is an "n by n" identity matrix (and "n" is the number of industries); the matrix A is called the "structure matrix", representing direct input requirements; the vectors X and Y (each of n by 1) represent outputs and final demands of n industries. The necessary and sufficient conditions for the existence of a general solution (2) is well known [5] and [11], and can be expected to be satisfied in empirical analysis. The matrix (I-A) is sometimes called the "Leontief matrix", and its inverse $(I-A)^{-1}$ represents total (direct and indirect) input requirements. From (2), it is clear that total input requirements for any set of final demands can be easily computed, once the inverse of the Leontief matrix is known. The spending impact of a hypothetical reallocation (and not elimination) of space expenditures can be evaluated simply by comparing the resulting levels of production corresponding to alternative patterns of final demand.

As to the impact of a reallocation of space expenditures on the level of employment, we also rely on a very simple model. In essence, we assume that the labor-output ratio (or the productivity of labor) for each industry remains constant at a certain level so that we may write (3) $X = CL$ and thus (4) $L = C^{-1}X$ where C is a diagonal matrix of n by n of which each diagonal element represents the productivity of labor in the corresponding industry, and L is a column vector of n by 1 of which each element represents the employment level of the corresponding industry. Once the labor-output ratio of each industry is known and the level of production is computed according to equation [2], the impact of a reallocation of space expenditure in terms of labor employment can be easily determined by comparing the labor requirements derived from equation (4) for alternative patterns of final demand.

7.3.4 Space Expenditure and Industrial Production

The most recent input-output table for the U.S., together with the Leontief matrix and its inverse, are based on the 1963 survey conducted by the Office of Business Economics of the U.S. Department of Commerce [16]. The entire production activities of the U.S. economy are classified into 81 industries, as shown in Table 7.3.1 (the same classification of 82 industries as that of the 1958 survey was, in fact, actually used, except "research and development" was eliminated and no longer considered as an industry). The present report is largely based on this input-output structure, except for research and development for which the data must be taken from the earlier 1958 input-output survey [14].

With the data on the inverse of the Leontief matrix, representing total input requirements for the production of one dollar of each output, readily available, it is straightforward to compute the impact on the production levels of any given amount of final demand. In order to evaluate the impact of $3 billion in space expenditures on economic-activity levels, we

Table 7.3.1

Industry Classification of Input-Output Tables and National Income Accounts

Industry No.	Industry Name: Input-Output Table (1)	Industry Name: National Income Account (2)
1 2	Livestock and livestock products Other agricultural products	Farms
3 4	Forestry & fisher products Agricultural, forestry & fishery services	Agricultural services, forestry, & fisheries
5 6	Iron & ferroalloy ores mining Nonferrous metal ores mining Coal Mining	Metal mining
7	Coal mining	Coal mining
8	Crude petroleum & natural gas	Crude petroleum & natural gas
9 10	Stone & clay mining & Chemical & fertilizer mineral mining	Mining & quarrying of nonmetallic minerals
11 12	New construction Maintenance & repair construction	Contract construction
13	Ordnance & Accessories	Grouped together with 60 & 61
14	Food & kindred products	Food & kindred product
15	Tobacco manufactures	Tobacco manufactures
16 17	Broad & narrow fabrics, yarn & thread mills Miscellaneous textile goods & floor covering	Textile mill products
18 19	Apparel Miscellaneous fabricated textile products	Apparel & other fabricated textile products
20 21	Lumber & wood products, except containers Wooden containers	Lumber & wood products except furniture
22 23	Household furniture Other furniture & fixtures	Furniture & fixtures
24 25	Paper & allied products, except containers Paperboard containers & boxes	Paper & allied products
26	Printing & publishing	Printing, publishing
27 28 29 30	Chemicals & selected chemical products Plastics & synthetic materials Drugs, cleaning & toilet preparations Paints & allied products	Chemicals & allied products
31	Petroleum refining & related industries	Petroleum refining & related industries
32	Rubber & miscellaneous plastics products	Rubber & miscellaneous plastic products
33 34	Leather tanning & industrial leather products Footwear & other leather products	Leather & leather products
35 36	Glass & glass products Stone & clay products	Stone, clay & glass products

Table 7. 3. 1

Industry No.	Input-Output Table (1)	National Income Account (2)
37 38	Primary iron & steel manufacturing Primary nonferrous metal manufacturing	Primary metal industries
39 40 41 42	Metal containers Heating, plumbin & structural metal products Stamping, screw machine products & bolts Other fabricated metal products	Fabricated metal products
43 44 45 46 47 48 49 50 51 52	Engines & turbines Farm machinery & equipment Construction, mining & oil field machinery Materials handling machinery & equipment Metalworking machinery & equipment Special industry machinery & equipment General industrial machinery & equipment Machine shop products Office, computing & accounting machines Service industry machines	Machinery, except electrical
53 54 55 56 57 58	Electrical industrial equipment & apparatus Household appliances Electric lighting & wiring equipment Radio, television & communication equipment Electronic components & accessories Miscellaneous electrical machinery equipment & supplies	Electrical machinery
59	Motor vehicles & equipment	Motor vehicles & motor vehicle equipment
60 61	Aircraft & parts Other transportation equipment	Transportation equipment & ordnance, except motor (including 13
62 63	Scientific & controlling instruments Optical, opthalmic & photographic equipment	Instruments
64	Miscellaneous manufacturing	Miscellaneous manufacturing industries
65	Transportation & warehousing	Transportation
66	Communications; except radio & TV broadcasting	Telephone & telegraph
67	Radio & TV broadcasting	Radio broadcasting & TV
68	Electric, gas, water & sanitary services	Electric, gas & sanitary service
69	Wholesale & retail trade	wholesale & retail trade
70	Finance & insurance	Finance & insurance
71	Real estate & Rental	Real estate
72	Hotels; personal & repair services, excluding automotive	Hotels & other lodging places personal services
73	Business services	Miscellaneous business services legal services Miscellaneous professional services

Table 7.3.1

Industry No.	Input-Output Table (1)	National Income Account (2)
74	*(See remark below)	
75	Automobile repair & services	Automobile repair, automobile
76	Amusements	Motion pictures Amusement & recreation services except motion pictures
77	Medical, education services & non-profit organiztions	Medical & other health services Educational services Nonprofit membership organizations
78	Federal government enterprises	Government enterprises
79	State & local government enterprises	Government enterprises
80	Gross imports of goods and services	Rest of the world
81	Business travel, entertainment and services	
82	Office supplies	

Remark: *Industry 74, research and development, is not treated as a separate industry in the 1963 input-output survey, though it was so treated in the 1958 survey.

need only know how the amount will be spent among different industries. For our subsequent analysis, we shall assume that it will be distributed among industries 13 and 60 according to the actual proportions of 1963 final demands for these two industries. Note that industry 13 is "ordnance and accessories" which actually includes all completed space vehicles, and that industry 60 is "aircraft and parts" which actually includes all parts of space vehicles.

Similarly, in order to evaluate the impact of a $3 billion expenditure for communication and transportation, we need only to know how this amount will be spent among different industries. In our subsequent analysis, we shall assume that it will be distributed between industries 56 and 61 according to the actual proportions of 1963 final demands for these two industries. Note that industry 57 is "radio, television and communication equipments," and industry 61 is "other transportation equipments", which excludes aircraft and parts.

In the cases of new construction, and medical and educational services, the evaluation of their impact on production levels is much easier, since each corresponds to one industry according to the classification used in the 1963 input-output table. Therefore, we need only to select the appropriate column from the inverse of the Leontief matrix and multiply it by whatever amount of expenditure we wish to consider; that is, $3 billion in our present case.

The results of these computations are provided in Table 7. 3. 2 for each of the 81 industries considered. For example, Table 7. 3. 2 shows that for each $3 billion increase (or decrease) of space expenditures, we may expect a $1, 212 million increase (or decrease) of production in industry 13 (ordnance and accessories) and a $2, 647 million increase (or decrease) of production in industry 60 (aircraft and parts), etc.

More relevant and perhaps more interesting results can be obtained by comparing column (1) of Table 7. 3. 2 with any other column of the same table. These results, obtained by subtracting column (1) from the corresponding rows of columns (2) to (5) in Table 7. 3. 2, are provided in

Table 7.3.2

Impact on Production Level Induced by a $3 Billion Change in Expenditures for Five Alternative Activities
(Millions of Dollars)

Industry No.	Space (1)	New Construction (2)	Communication and Transportation Equipments (3)	Medical and Educational Services (4)	Research and Development (5)
1	$9.4	$14.4	$10.9	$24.6	$16.4
2	9.5	33.5	12.3	24.6	16.6
3	1.8	22.3	5.9	1.3	2.4
4	0.8	3.1	1.2	1.6	1.3
5	10.6	15.2	14.8	0.9	14.1
6	22.3	13.8	15.8	1.0	22.4
7	8.8	13.7	11.1	6.1	13.0
8	20.5	49.3	20.4	23.5	29.5
9	3.5	51.1	4.1	2.4	4.0
10	1.8	3.2	2.1	1.0	4.0
11	—	3,000.0	—	—	—
12	27.0	34.8	28.5	101.4	40.0
13	1,211.8	1.6	22.8	0.3	685.2
14	25.1	26.5	25.4	63.5	40.6
15	1.7	1.3	1.6	1.8	1.9
16	10.6	13.9	17.5	4.1	18.3
17	5.2	12.7	14.3	1.7	11.2
18	6.1	4.9	7.0	1.4	7.0
19	1.1	2.4	5.3	2.3	4.9
20	17.1	250.3	64.3	10.1	19.0
21	2.5	1.7	2.3	0.4	2.2
22	3.7	17.2	43.1	0.2	8.6
23	8.1	9.4	1.9	0.2	3.1
24	29.5	48.4	44.7	34.4	52.4
25	13.6	14.6	21.0	6.5	22.3
26	40.2	55.6	45.3	83.0	47.0
27	51.5	68.3	61.0	30.2	114.4
28	23.5	22.3	35.7	6.0	34.6
29	4.2	5.6	4.2	60.9	29.1
30	6.9	23.4	11.5	5.5	8.5
31	34.1	94.8	33.8	31.5	47.5
32	56.7	46.2	60.6	12.8	73.1
33	0.7	0.7	0.8	0.3	1.0
34	0.8	0.7	0.8	0.7	1.2
35	6.5	11.4	28.6	3.7	16.4
36	18.0	313.2	17.9	4.9	29.1
37	201.9	282.3	286.5	13.1	220.8
38	287.3	170.8	199.8	9.4	217.3
39	2.4	4.3	2.9	3.6	4.3
40	7.9	294.7	43.6	3.6	20.5
41	62.1	22.6	76.4	2.9	73.6
42	73.0	85.7	95.9	6.5	73.9
43	11.2	6.8	32.1	0.9	40.3
44	1.9	2.4	7.5	0.7	10.8
45	5.0	18.6	5.2	1.0	8.3
46	4.2	15.5	3.3	0.7	3.7
47	83.1	11.0	41.5	1.3	116.3

48	5.0	4.5	5.5	1.2	9.0
49	35.9	23.6	62.3	1.6	38.9
50	130.6	7.3	23.1	1.0	85.1
51	3.9	3.3	13.3	1.5	14.5
52	6.0	27.3	10.3	1.4	15.4
53	30.0	34.7	98.2	2.9	159.3
54	6.8	14.0	18.9	1.6	91.4
55	17.9	56.8	41.5	1.9	66.3
56	195.3	8.5	2,318.2	3.3	299.8
57	82.8	5.0	392.7	2.5	160.9
58	14.9	7.0	9.9	1.5	27.2
59	20.0	17.5	32.8	5.0	185.5
60	2,647.1	5.5	55.4	1.4	1,261.8
61	7.5	5.9	952.7	0.9	11.3
62	60.1	16.4	22.1	24.8	118.5
63	21.8	3.3	8.4	9.1	26.5
64	9.2	13.0	12.0	10.6	20.3
65	99.7	212.4	114.7	65.5	126.0
66	47.6	32.2	36.6	47.4	30.5
67	8.6	13.6	8.7	8.2	6.6
68	67.3	77.5	66.6	125.5	62.4
69	144.0	347.7	191.1	97.9	178.7
70	42.8	62.2	44.8	45.2	55.0
71	63.3	90.5	81.0	289.4	94.9
72	20.1	10.3	12.5	24.6	17.4
73	137.5	217.6	139.4	107.2	104.9
74	—	—	—	—	3,003.0
75	12.3	23.3	11.7	19.2	8.9
76	5.1	6.9	5.2	8.9	9.4
77	7.7	6.1	6.2	3,030.8	312.8
78	15.0	14.7	15.3	31.9	13.9
79	13.5	20.2	14.1	23.3	13.4
80	83.0	93.2	127.9	22.5	84.4
81	59.2	44.5	57.1	63.0	72.5
82	8.7	5.6	8.1	14.3	7.4
TOTAL	6,565.5	6,748.8	6,511.8	4,695.6	9,026.3

Remarks:

Computations for columns (1) through (4) based on the 1963 input-output survey, Survey of Current Business, November, 1969. The "space" activity is defined as the joint activity of industries 13 and 60, and the "communication and the transportation equipments activities" is defined as the joint activity of industries 56 and 61, the weights being the 1963 actual final demands.

Computations for column (5) are based on the 1958 input-output survey, Survey of Current Business, Sept., 1965.

Table 7.3.3. They indicate the net impact of the reallocation of a $3 billion space expenditure on each of the four alternatives. For example, the net impact of reallocating a $3 billion space expenditure into new construction would be a reduction in production of $1,210 million and $2,642 million for industries 13 and 60 (ordnance and aircraft) respectively, etc.

An even more meaningful figure is, perhaps, relative change rather than absolute change, since industry sizes vary considerably. For this reason, we have further computed relative changes as the ratios of figures in Table 7.3.3 to the estimated 1970 production levels of the corresponding industry. The 1970 production levels of all industries were estimated by increasing the 1963 production levels by a fixed proportion as found in the observed GNP growth rate. The results of the relative impact of the reallocation of a $3 billion space expenditure are shown in Table 7.3.4. It is clear that most of the industries are affected by less than 1% in terms of the production level regardless of whether the $3 billion space expenditure is reallocated into new construction, communication and transportation equipment, medical and educational services, or research and development in general.

To recapitulate the major results of our analysis on the impact of the hypothetical reallocation of space expenditures in terms of production level, we present Table 7.3.5 below. The table is a summary of both Tables 7.3.3 and 7.3.4. The impact on the production levels of various industries caused by the reallocation of a $3 billion fund from space expenditures into each of the four alternative activities are presented in separate columns. Note, however, that only the industries which would be affected by more than 1% are presented in the table and that the production level is expressed in terms of billion dollars rather than million dollars as in the previous tables.

It is clear that industries 13 and 60 (ordnance and aircraft) would be adversely affected by more than 10% in terms of the productions level except when the $3 billion space expenditure is reallocated into research and development in general. In this case, a large portion of this fund would be reallocated back to space research and development. It is also clear that while the impact of the reallocation of a $3 billion space expenditure

Table 7.3.3

Absolute Impact on Production Levels of the Reallocation of $3 Billion from Space to Alternative Expenditures

(Millions of Dollars)

Industry No.	New Construction (1)	Communication and Transportation Equipments (2)	Medical and Educational Services (3)	Research and Development (4)
1	$ 5.0	$ 1.5	$15.2	$ 7.1
2	24.0	2.7	15.0	7.1
3	20.5	4.2	- 0.5	0.6
4	2.3	0.4	0.8	0.5
5	4.5	4.2	- 9.8	3.5
6	-8.4	-6.4	-21.3	0.1
7	4.9	2.3	- 2.7	4.2
8	28.9	- 0.1	2.9	9.1
9	47.7	0.6	-1.1	0.5
10	1.4	0.3	-0.8	2.2
11	3,000.0	—	—	—
12	7.8	1.5	74.4	13.0
13	-1,210.2	-1189.0	- 1,211.5	-526.5
14	1.3	0.3	38.4	15.5
15	-0.4	-0.1	0.1	0.3
16	3.3	6.8	-6.5	7.7
17	7.6	9.1	-3.5	6.1
18	- 1.1	1.0	-4.7	0.9
19	1.4	4.2	1.3	3.8
20	233.1	47.1	- 7.0	1.9
21	-0.8	-0.2	- 2.2	-0.3
22	13.6	39.4	- 3.5	4.9
23	1.3	-6.2	- 7.9	- 5.0
24	18.9	15.3	5.0	22.9
25	1.0	7.3	-7.1	8.8
26	15.4	5.2	42.8	6.8
27	16.9	9.5	-21.2	62.9
28	-1.2	12.1	- 17.6	11.1
29	1.3	-0	56.7	24.9
30	16.5	4.7	-1.3	1.8
31	60.7	-0.3	- 2.6	13.5
32	-10.5	3.9	- 43.9	-49.5
33	0	0.1	-0.5	0.3
34	-0.1	0	-0.1	0.4
35	4.9	22.1	-2.8	9.9
36	295.2	-0.1	-13.1	11.1
37	80.4	84.6	-188.8	18.9
38	-116.5	-87.5	-277.9	-69.9
39	1.9	0.5	1.2	1.9
40	286.9	35.8	-4.2	12.6
41	-39.4	14.3	-59.2	11.5
42	12.7	23.0	-66.5	-65.0
43	-4.4	20.9	-10.3	29.1
44	0.6	5.7	-1.2	8.9
45	13.6	0.2	-3.9	3.3
46	11.3	-0.9	-3.5	-0.5
47	-72.1	-41.6	-81.8	33.2

Table 7.3.3 (continued)

48	-0.5	0.5	-3.8	4.0
49	-12.2	26.4	-34.3	3.0
50	-123.3	-107.6	-129.7	-45.5
51	-0.6	9.3	-2.4	10.7
52	21.3	4.3	-4.5	9.4
53	4.7	68.2	-27.1	129.3
54	7.2	12.1	-5.3	84.6
55	39.0	23.6	-15.9	48.4
56	-186.9	2,122.9	-192.1	104.0
57	-77.7	309.9	-80.2	77.9
48	-7.8	-4.9	-13.3	12.3
59	-2.5	12.8	-15.0	165.5
60	-2,641.7	-2,591.7	-2,645.7	-1,385.4
61	-1.7	945.0	-6.6	3.8
62	-43.7	-37.9	-35.3	58.4
63	-18.5	-13.4	-12.7	4.7
64	3.7	2.8	1.4	11.1
65	112.7	15.0	-34.2	26.3
66	-15.3	-11.0	-0.2	-17.1
67	5.0	0.1	-0.3	-0.2
68	10.3	-0.7	58.2	-4.8
69	203.7	47.0	-46.1	34.7
70	19.4	2.0	2.4	12.2
71	27.3	17.8	226.2	31.7
72	-9.8	-7.6	4.5	-2.7
73	80.1	1.8	-30.3	-32.6
74	—	—	—	3,003.0
75	11.0	-0.6	6.9	-3.4
76	1.8	0.0	3.7	4.4
77	-1.5	-1.5	3,023.1	305.1
78	-0.3	0.2	16.9	-1.1
79	6.7	0.6	9.8	-0.1
80	10.2	45.0	-60.5	1.4
81	-14.7	-2.0	3.8	12.3
82	-3.1	-0.6	5.7	-1.2
TOTAL	$+183.3	$-53.8	$-1,870.0	$ +2,328.4

Remark: The results of this table are obtained by subtracting columns (2) through (5) of Table 7.3.2 from Column (1) of the same table.

Table 7.3.4

Relative Impact on Production Levels of the Reallocation of $3 Billion from Space to Alternative Expenditures

(Percent of 1970 Production Level)

Industry No.	Alternatives to Space Activity: New Construction (1)	Communication and Transportation Equipments (2)	Medical and Educational Services (3)	Research and Development (4)
1	0.01%	0.00%	0.03%	0.02%
2	0.05	0.01	0.03	0.02
3	0.71	0.14	-0.02	0.02
4	0.08	0.01	0.03	0.02
5	0.19	0.18	-0.41	0.15
6	-0.33	-0.25	-0.84	0.00
7	0.11	0.05	-0.06	0.10
8	0.14	-0.00	0.01	0.04
9	1.42	0.02	-0 03	0.01
10	0.12	0.03	-0.07	0.19
11	2.77	—	—	—
12	0.02	0.00	0.23	0.04
13	-11.61	-11.41	-11.62	-5.04
14	0.00	0.00	0.03	0.01
15	-0.00	-0.00	0.00	0.00
16	0.02	0.03	-0.03	0.00
17	0.12	0.15	-0.06	0.10
18	-0.00	0.00	-0.02	0.00
19	0.03	0.08	0.02	0.07
20	1.32	0.27	-0.04	0.01
21	-0.11	-0.03	-0.31	-0.04
22	0.20	0.59	-0.05	0.07
23	0.04	-0.19	-0.25	-0.16
24	0.09	0.07	0.02	0.10
25	0.01	0.09	-0.09	0.11
26	0.06	0.02	0.16	0.02
27	0.06	0.03	-0.08	0.22
28	-0.01	0.12	-0.17	0.11
29	0.01	-0.00	0.38	0.02
30	0.41	0.11	-0.03	0.04
31	0.17	-0.00	-0.01	0.04
32	-0.06	0.02	-0.27	-0.30
33	-0.00	0.01	-0.03	0.02
34	-0.00	0.00	-0.00	0.01
35	0.10	0.46	-0.06	0.20
36	1.87	-0.00	-0.08	0.07
37	0.20	0.21	-0.46	0.05
38	-0.19	-0.37	-1.18	-0.29
39	0.05	0.01	0.03	0.05
40	1.93	0.24	-0.03	0.08
41	-0.48	0.17	-0.72	0.14
42	0.09	0.15	-0.45	-0.44
43	-0.11	0.53	-0.26	0.73
44	0.01	0.11	-0.02	0.17
45	0.20	0.00	-0.06	0.05
46	0.42	-0.03	-0.13	-0.02
47	-0.85	-0.49	-0.96	0.39

Table 7.3.4 (continued)

48	-0.01	0.01	-0.06	0.06
49	-0.14	0.30	-0.39	0.03
50	-3.30	-2.88	-3.47	-1.22
51	-0.01	0.14	-0.04	0.16
52	0.38	0.08	-0.08	0.16
53	0.04	0.63	-0.25	1.20
54	0.09	0.16	-0.07	1.09
55	0.76	0.46	-0.31	0.95
56	-0.91	10.32	-0.93	0.50
57	-1.04	4.15	-1.08	1.04
58	-0.21	-0.13	-0.36	0.33
59	-0.00	-0.02	-0.02	0.25
60	-11.16	-10.94	-11.17	-5.65
61	-0.02	11.68	-0.08	0.05
62	-0.62	-0.54	-0.50	0.82
63	-0.44	-0.32	-0.30	0.11
64	0.03	0.02	0.01	0.09
65	0.17	0.02	-0.05	0.04
66	-0.07	-0.05	-0.00	-0.10
67	0.13	0.00	-0.01	-0.05
68	0.02	-0.00	0.12	-0.01
69	0.10	0.02	-0.02	0.02
70	0.03	0.00	0.00	0.02
71	0.02	0.01	0.16	0.02
72	-0.04	-0.03	0.02	-0.01
73	0.13	-0.00	-0.05	-0.05
74	—	—	—	—
75	0.06	-0.00	0.04	-0.02
76	0.01	0.00	0.03	0.03
77	-0.00	-0.00	5.51	0.55
78	-0.00	0.00	0.17	-0.01
79	0.06	0.01	0.08	0.00
80	—	—	—	—
81	-0.11	-0.02	0.03	0.09
82	-0.09	-0.02	0.16	-0.03
Total	+0.010%	-0.003%	-0.105%	+0.130%

Remark: The production levels of 1970 were computed on the assumption that all industries increased their productions at the same rate as the growth of GNP from 1963 to 1970.

Table 7.3.5

Major Impact of Reallocation of $3 Billion

Space Expenditure on Production Level*

(Billions of Dollars)

	Industry Number and Name	Alternatives to Space Activity: New Construction (1)	Communication and Transportation Equipment (2)	Medical and Educational Services (3)	Research and Development (4)
9	Stone and clay mining and quarrying	$0.05 (1.4%)	—	—	—
11	New construction	3.00 (2.8%)	—	—	—
13	Ordnance and accessories	-1.21 (-11.6%)	$-1.17 (-11.2%)	$-1.21 (-11.6%)	$-0.53 (-5.0%)
20	Lumber and wood products except containers	0.23 (1.3%)	—	—	—
36	Glass and glass products	0.30 (1.9%)	—	—	—
38	Primary nonferrous metal products	—	—	-0.28 (-1.2%)	—
40	Heating, plumbing and structural metal products	0.29 (1.9%)	—	—	—
50	Machine shop products	-0.12 (-3.3%)	-0.11 (-2.9%)	—	-0.05 (-1.2%)
53	Electric industrial equipment and apparatus	—	—	—	0.13 (1.2%)
54	Household appliances	—	—	—	0.09 (1.1%)
56	Radio, TV and Communication Equipment	—	2.12 (10.3%)	—	—
57	Electronic component and accessories	-0.08 (-1.0%)	0.31 (4.2%)	-0.08 (-1.0%)	0.08 (1.0%)
60	Aircraft and parts	-2.64 (-11.1%)	-2.59 (-10.9%)	-2.65 (-11.2%)	-1.39 (-5.6%)
61	Other transportation equipment	—	0.95 (11.7%)	—	—
77	Medical and educational services	—	—	3.02 (5.6%)	—
	Total	$0.18 (0.01%)	$-0.05 (0%)	$-1.87 (-0.11%)	$2.33 (0.13%)

* Only the industries that would be affected by more than 1% in terms of the relative changes in production level are listed. The Figures in parentheses are percentage changes from the 1970 production level (estimated).

to the communication and transportation equipment industries would be considerable to those industries (industries 56 and 61), the allocation of the same amount into new construction would have a relatively small effect on that industry in terms of the relative changes of the level of production. The impact of the reallocation of $3 billion into medical and educational services would be moderate to that industry and likely to be widely spread over many industries. Finally, the reallocation of $3 billion into research and development in general is likely to affect that industry considerably, though the effect is not explicitly shown in the table, since it is not treated as a separate industry in the 1963 input-output tables. To give a general idea, the estimated total research and development fund is approximately $27 billion in 1970 (the definition may not be entirely compatible with that used in the 1958 input-output table). Therefore, a $3 billion new fund would constitute more than a 10% increase to research and development funds.

7.3.5 Space Expenditure and Labor Employment

For some purposes, the impact on the employment level caused by the hypothetical reallocation of space expenditures may be more relevant than the impact on the production level. After we have completed an analysis of the impact on the production level, as we have just done, it is not difficult to convert the results of Tables 7.3.2 and 7.3.3 into the impact on employment level. Furthermore, if data on employment levels by industry can be obtained it is also possible to obtain results similar to Table 7.3.4.

Referring to equations (3) and (4), the productivity of labor C (or the labor-output ratio C^{-1}) can be computed easily for each industry, once the data on output X and employment L by various industries are available. Since employment data are not available from the 1963 input-output survey, the employment data from the national income accounts, which are easily accessible, can be used. The industry classifications used in these two sets of data are not exactly the same. Reconciliation can, however, be achieved without very much difficulty, as is shown in Table 7.3.1. Based on this classification and the data on 1963 industry employment levels obtained from [15, Table 6.4, p. 105], we have obtained the productivity of labor for each industry or group of industries as shown in Table 7.3.6. These results were then used to con-

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Table 7.3.6

Annual Output Per Man-Year in 1963

Industry No.	Total Output (Million Dollars) (1)	Labor Input (Thousand Man-Years) (2)	Output per Man-Year (Thousand Dollars) (3)
1 and 2	$53,950	1,745	$30.9
3 and 4	3,523	163	21.6
5 and 6	2,948	81	36.4
7	2,637	148	17.8
8	12,265	289	42.4
9 and 10	2,720	116	23.5
11 and 12	85,313	2,958	28.8
13 grouped together with 60 and 61	-	-	-
14	74,263	1,744	42.6
15	7,425	89	83.4
16 and 17	16,799	895	18.8
18 and 19	21,203	1,274	16.6
20 and 21	11,074	588	18.8
22 and 23	5,990	389	15.4
24 and 25	17,867	622	28.7
26	16,283	930	17.5
27 to 30	34,749	865	40.2
31	21,837	192	114.0
32	9,891	417	23.7
33 and 34	4,394	347	12.7
35 and 36	12,480	600	20.8
37 and 38	38,890	1,176	33.1
39 to 42	25,359	1,146	22.1
43 to 52	34,944	1,533	22.8
53 to 58	33,475	1,558	21.5
59	40,031	744	53.8
60, 61 and 13	25,513	1,133	22.6
62 and 63	6,814	362	18.8
64	7,152	391	18.3
65	39,215	2,250	17.5
66	13,495	730	18.5
67	2,308	88	26.2
68	29,660	614	48.4
69	120,613	10,140	11.9
70	33,700	2,082	16.2
71	83,887	551	152.3
72	15,370	1,456	10.6
73	35,945	1,414	25.5
74	-	-	-
75	10,866	266	40.9
76	7,697	476	16.2
77	33,160	3,814	8.7
78	5,864	671	8.7
79	7,236	386	18.8
80	-	-	-
81	7,793	-	-
82	2,106	-	-
TOTAL	$1,078,000	59,333	$18.2

Remark: Column (1) based on 1963 input-output table, Survey of Current Business, November, 1969; and column (2) based on national income accounts data, The National Income and Product Accounts of the United States, 1929-1965, Table 6.4, p. 105.

vert the results of impact on production levels as shown in Tables 7. 3. 2 and 7. 3. 3 into the impact on employment levels as shown in Tables 7. 3. 7 and 7. 3. 8. Since the data on employment are not available for each of the 81 industries previously considered, in many cases the impact on employment levels is shown only for groups of closely related industries. In Table 7. 3. 7, for example, we find that a change of $3 billion in space expenditures would induce an increase or a decrease of approximately 171 thousand man years of employment in a group of transportation equipment and ordnance industries, including industries 13, 60 and 61, but excluding motor vehicles. In Table 7. 3. 8, the net impact of the hypothetical reallocation of $3 billion from space to alternative expenditures in terms of absolute changes in employment levels are presented. For example, it is shown that the reallocation of $3 billion from space to communication and transportation would decrease the employment of ordnance, aircraft, and transporation equipment industries (industries 13, 60 and 61 by 127 thousand man years and increase the employment of electrical machinery (industries 53 to 58) by 118 thousand man years, etc. Finally, in Table 7. 3. 9, these absolute changes in employment levels are expressed as percentages of the actual 1970 employment levels [17, Table 6. 4,p. 36] of the corresponding industry or group of industries. For example, the impact of the hypothetical reallocation of $3 billion from space to communication and transportation equipment on the employment of ordnance, aircraft, and transportation equipment industries (industries 13, 60 and 61) amounts to a reduction of approximately 10% of total employment in these industries. Similarly, the impact on the employment of electrical machinery (industries 53 to 58) amounts to an increase of approximately 6% of total employment of these industries.

To summarize the major impact of the hypothetical reallocation of a $3 billion space expenditure on employment levels as presented in Tables 7. 3. 8 and 7. 3. 9, we have prepared the following Table 7. 3. 10. In this table only major impact on employment levels for industries with more than 1% change in employment has been listed. Under each absolute change of employment, in terms of thousand man years, the percentage change of employment is also provided in the parentheses. For example, the reallocation of a $3 billion space expenditure into new construction activity

Table 7.3.7

Impact on Employment Level Induced by a
$3 Billion Change in Expenditures for Five Alternative Activities

(Thousand Man-Years)

Industry No.	Space (1)	New Construction (2)	Communication and Transportation Equipments (3)	Medical and Educational Services (4)	Research and Development (5)
1 and 2	0.6	1.6	0.8	1.6	1.1
3 and 4	0.1	1.1	0.4	0.2	0.2
5 and 6	0.9	0.8	0.8	0.0	1.0
7	0.5	0.8	0.6	0.3	0.7
8	0.5	1.2	0.5	0.6	0.7
9 and 10	0.2	2.3	0.3	0.1	0.3
11 and 12	0.9	105.4	1.0	3.5	1.4
13 grouped together with 60 and 61					
14	0.6	0.6	0.6	1.5	1.0
15	0.0	0 0	0.0	0.0	0.0
16 and17	0.9	1.4	1.7	0.3	1.6
18 and 19	0.5	0.4	0.7	0.2	0.7
20 and 21	1.0	13.4	3.5	0.5	1.1
22 and 23	0.7	1.7	2.9	0.0	0.8
24 and 25	1.5	2.2	2.3	1.4	2.6
26	2.2	3.2	2.6	4.7	2.7
27 to 30	2.1	3.0	2.8	2.5	4.6
31	0.3	0.8	0.3	0.3	0.4
32	2.4	1.9	2.6	0.5	0.3
33 and 34	0.2	0.2	0.2	0.1	0.2
35 and 36	1.2	15.6	2.3	0.4	2.2
37 and 38	14.8	13.7	14.7	0.7	13.3
39 to 42	6.6	18.4	9.9	0.8	4.8
43 to 52	12.6	5.2	8.8	0.5	15.0
53 to 58	16.1	5.8	134.0	0.7	37.4
59	0.4	0.3	0.6	0.1	3.4
60, 61 & 13	171.0	0.6	45.7	0.1	86.8
62 and 63	4.6	1.1	1.6	1.8	7.7
64	0.5	0.7	0.7	0.6	1.1
65	5.7	12.1	6.6	3.7	7.2
66	2.6	1.7	2.0	2.6	1.6
67	0.3	0.5	0.3	0.3	0.3
68	1.4	1.6	1.4	2.6	1.3
69	12.1	29.2	16.1	8.2	15.0
70	2.6	3.8	2.8	2.8	3.4
71	0.4	0.6	0.5	1.9	0.6
72	1.9	1.0	1.2	2.3	1.6
73	5.4	8.5	5.5	4.2	4.1
74	-	-	-	-	165.2
75	0.3	0.6	0.3	0.5	0.2
76	0.3	0.4	0.3	0.5	0.6
77	0.9	0.7	0.7	348.4	36.0
78	1.7	1.7	1.8	3.7	1.6
79	0.7	1.1	0.8	1.2	0.7
80	4.6	5.1	6.0	1.2	4.6
81	3.3	2.4	3.3	3.5	4.0
82	0.5	0.3	0.5	0.8	0.4
TOTAL	288.6	275.0	292.5	412.6	282.0

Remark: Computations of industries 80 to 82 employment based on the average output-labor ratio of all industries.

Table 7.3.8

Absolute Impact on Employment Level of the Reallocation of $3 Billion from Space to Alternative Expenditures
(Thousand Man-Years)

Industry No.	Alternatives to Space Activity: New Construction (1)	Communication and Transportation Equipments (2)	Medical and Educational Services (3)	Research and Development (4)
1 and 2	1.0	0.1	1.0	0.5
3 and 4	1.0	0.2	0.0	0.1
5 and 6	-0.1	-0.1	-0.9	0.1
7	0.3	0.1	-0.2	0.2
8	0.7	-0.0	0.1	0.2
9 and 10	2.1	0.0	-0.0	0.1
11 and 12	104.5	0.1	2.6	0.5
13 grouped together with 60 and 61	-	-	-	-
14	0.0	0.0	0.9	0.4
15	-0.0	-0.0	0.0	0.0
16 and 17	0.6	0.9	-0.5	0.8
18 and 19	0.0	0.4	-0.2	0.3
20 and 21	12.4	2.5	-0.5	0.1
22 and 23	1.0	2.2	-0.7	0.0
24 and 25	0.7	0.8	-0.0	1.1
26	0.9	0.3	2.4	0.4
27 to 30	0.8	0.6	0.5	2.5
31	0.5	-0.0	-0.0	0.1
32	-0.4	0.2	-1.9	-2.1
33 and 34	-0.0	0.0	-0.0	0.1
35 and 36	14.4	1.1	-0.7	1.0
37 and 38	-1.1	-0.0	-14.1	-1.5
39 to 42	11.9	3.2	-5.8	-1.8
43 to 52	-7.3	-3.6	-12.2	2.4
53 to 58	-10.4	117.7	-15.4	21.2
59	-0.0	0.2	-0.3	3.0
60, 61 and 13	-170.6	-126.5	-171.0	-84.6
62 and 63	-3.3	-2.7	-2.6	3.4
64	0.2	0.2	0.1	0.6
65	6.4	0.9	-2.0	1.5
66	-0.8	-0.6	-0.0	-1.0
67	0.2	0.0	-0.0	0.0
68	0.2	-0.0	1.2	-0.1
69	17.1	4.0	-3.9	2.9
70	1.2	0.1	0.1	0.8
71	0.2	0.1	1.5	0.2
72	-0.9	-0.7	0.4	-0.3
73	3.1	0.1	-1.2	-1.3
74	-	-	-	(165.2)
75	0.3	-0.0	0.2	-0.1
76	0.1	-0.0	0.2	0.3
77	-0.2	-0.2	347.5	35.1
78	-0.0	0.0	1.9	-0.1
79	0.4	0.0	0.5	0.0
80	0.5	1.4	-3.4	0.0
81	-0.9	0.0	0.2	0.7
82	-0.2	0.0	0.3	-0.1
TOTAL	-13.6	3.9	124.0	152.8

Remark: The results of this table are obtained by subtracting columns (2) through (5) of Table 7.3.7 from column (1) of the same table.

Table 7.3.9

Relative Impact on Employment Levels of the Reallocation of $3 Billion from Space to Alternative Expenditures
(Percent of 1970 Employment Level)

Industry No.	Alternatives to Space Activity: New Construction (1)	Communication and Transportation Equipments (2)	Medical and Educational Services (3)	Research and Development (4)
1 and 2	0.07%	0.01%	0.08%	0.04%
3 and 4	0.60	0.11	0.00	0.05
5 and 6	-0.11	-0.11	-0.84	0.11
7	0.21	0.07	-0.14	0.14
8	0.26	0.00	0.04	0.07
9 and 10	1.81	0.09	-0.09	0.09
11 and 12	2.99	0.00	0.07	0.02
13 grouped together with 60 and 61				
14	0.00	0.00	0.05	0.02
15	0.00	0.00	0.00	0.00
16 and 17	0.06	0.09	-0.05	0.08
18 and 19	0.00	0.02	-0.01	0.02
20 and 21	2.13	0.43	-0.07	0.02
22 and 23	0.20	0.46	-0.17	0.00
24 and 25	0.10	0.26	-0.01	0.16
26	0.08	0.03	0.22	0.04
27 to 30	0.09	0.07	0.05	0.24
31	0.26	0.00	0.00	0.05
32	-0.09	0.03	-0.33	-0.36
33 and 34	0.00	0.00	0.00	0.03
35 and 36	2.23	0.16	-0.12	0.16
37 and 38	-0.08	-0.01	-1.07	-0.11
39 to 42	0.85	0.24	-0.43	-0.13
43 to 52	-0.30	-0.18	-0.61	0.12
53 to 58	-0.54	6.12	-0.81	1.10
59	-0.01	-0.02	-0.04	0.37
60, 61 and 13	-13.70	-10.00	-13.74	-6.78
62 and 63	-0.71	-0.58	-0.54	0.72
64	0.05	0.05	0.02	0.14
65	0.27	0.04	-0.08	0.65
66	-0.09	-0.06	0.00	-0.10
67	0.17	0.00	0.00	0.00
68	0.03	0.00	0.17	-0.01
69	0.13	0.03	-0.03	0.02
70	0.03	0.01	0.01	0.03
71	0.03	0.02	0.73	0.03
72	-0.05	-0.04	0.02	-0.02
73	0.14	0	-0.05	-0.06
74	-	-	-	-
75	0.09	0	0.06	-0.03
76	0.02	0	0.03	0.05
77	0	0	6.31	0.64
78	0	-0.12	-0.17	-0.01
79	0.27	0	0.11	0
80	-	-	-	-
81	-	-	-	-
82	-	-	-	-
TOTAL	-0.02%	0.01%	0.22%	0.21%

Remark: Employment levels of industries 80, 81 and 82 cannot be easily determined.

would reduce the employment of ordnance, aircraft and transportation equipment industries (industries 13, 60 and 61) by approximately 171 thousand persons annually, which is about 14% of the 1970 employment level of these industries. The effect will be similar if medical and educational services are chosen as the alternative space expenditure. The decline in the employment of these industries would be approximately 127 thousand persons if the communication and transportation equipment industry is chosen as the alternative to space expenditure. In either of these cases, the reduction in employment will be more than 10% of the 1970 employment level. In the event that research and development is chosen as the alternative to space expenditure, the decline of employment in ordnance, aircraft and transportation equipment industries would be approximately 85 thousand persons, which is about 6.8% of the 1970 employment level of these industries.

On the other hand, the hypothetical reallocation of $3 billion of space expenditures into new construction activity would increase the employment of that industry and the repairment and maintenance industries (industries 11 and 12) by more than 100 thousand persons, which is about 3% of the 1970 employment level of these industries. Similarly, the reallocation of a $3 billion space expenditure into the communication and transportation equipment industries or medical and educational services would increase the employment of the electric machinery industry (industries 53 to 58) by 118 thousand persons or the employment of medical and educational services by 348 thousand persons. In terms of relative changes, both figures represent approximately 6% of the 1970 employment levels of the corresponding industries.

7.3.6 Concluding Remarks

In this section we have attempted to evaluate the impact of space expenditures in terms of both production and employment levels. In particular, we have examined in great detail the impact of the reallocation (and not reduction) of a $3 billion space expenditure into one of the following four alternative activities: new construction, communication and transportation equipment, medical and educational services, and finally research and development in general. The open-static input-output model employed in the present report is very simple, though practical computations may be somewhat tedious. The major results as summarized in Tables 7.3.5 and 7.3.10 clearly show that the impact of the reallocation of a $3 billion space expenditure into each of the four alternative activities would produce only a very negligible impact on the economy as a whole, though some industries may be affected considerably, as long as this $3 billion is spent in these sectors in addition to present activity levels.

It may be reminded that in computing the relative changes of production level we have assumed that the activity levels of all industries increase proportionately from 1963 to 1970 at the observed GNP growth rate. On the other hand, in computing the relative changes of employment level, we have assumed that the productivities of labor (or labor-output ratios) of all industries in 1970 remain at their 1963 levels. Neither of these assumptions, of course, is very realistic. We believe, however, that both assumptions can be expected to provide good approximations. This conviction has been greatly enhanced by the close similarity one can detect from Tables 7.3.4 and 7.3.9 and particularly the results shown in the parentheses of Tables 7.3.5 and 7.3.10. Further improvements on the input-output model itself or refinements of some of the underlying assumptions adopted for inference would undoubtedly increase the reliability of the numerical results. From our analysis so far, we can confidently conclude that the spending impact of space expenditures on the national economy as a whole appears to be negligible and, therefore, should not be overstated. After all, space expenditures, at $3 billion, represent only 0.3% of the total U. S. Gross National Product.

7.4 Remarks and Conclusions

The purpose of this chapter is to examine the relationship between the national economy and space activity. More specifically, we have attempted to answer two major questions: how do national economic conditions, among other factors, influence the level of space expenditures, and, what may be the impact of space expenditures on the various sectors of the economy? In order to answer the first question so that we may be able to project future space

Table 7.3.10

Major Impact of Reallocation of a $3 billion

Space Expenditure on Employment Level *
(Thousands of Persons)

Industry Number and Name	Alternatives to Space Activity			
	New Construction (1)	Communication and Transportation Equipments (2)	Medical and Educational Services (3)	Research and Development (4)
9, 10 Mining and quarrying of non-metallic minerals	2 (1.8%)	——	——	——
11, 12 Contract construction	104 (3.0%)	——	——	——
13, 60, 61 Transportation equipments and ordnance, except motor vehicles	-171 (-13.7%)	-127 (-10.0%)	-171 (-13.7%)	-85 (-6.8%)
20, 21 Lumber & wood products, except furniture	12 (2.1%)	——	——	——
35, 36 Stone, clay and glass products	——	——	-14 (-1.1%)	——
37, 38 Primary metal industry				
53 to 58 Electrical machinery	——	118 (6.1%)	——	21 (1.1%)
77 Medical and educational services	——	——	348 (6.3%)	——
Total	-13.6 (-0.02%)	3.9 (0.01%)	124.0 (0.22%)	152.8 (0.21%)

* Only the industries that would be affected by more than 1% in terms of the relative changes in employment level are listed. Figures in parentheses are percentage changes from the 1970 employment level (actual).

budgets, we have adopted a macro-econometric model approach. On the other hand, to answer the second question so that the impact of space expenditures on the various sectors of the economy can be evaluated in terms of their effects on the sectors' levels of production and employment, we have employed a micro-activity analysis approach.

In pursuing the macro-econometric model approach for an analysis of the future national economy and space expenditures, we have formulated an econometric model of the United States, which consists of a dynamic system of twenty-eight equations. The model was first evaluated by examining its performance on predictions for the period 1965-70, then employed to generate alternative simulations for the period 1971-80. Included in our simulations are different situations reflecting expansionary, neutral, and restrictive fiscal and monetary policies, respectively.

In addition, in order to use our projections of economic conditions for the projection of space expenditures, we have demonstrated that the level of past space expenditures had been clearly affected by the level of government spending in general and other economic conditions such as the rate of inflation. Based on such an additional empirical relationship, several alternative projections of space expenditures for the period 1971-80 have been presented. According to the neutral policy, the level of space expenditures is projected to rise gradually from $3.3 billion in 1971 to $4.1 billion in 1980 (in terms of 1970 constant dollars). According to the expansionary and restrictive policies, the level of space expenditures is projected to rise from $3.5 and $3.2 billion in 1971 to $3.7 and $4.6 billion respectively in 1980 (again, in terms of 1970 constant dollars).

It must be realized that our projections of both economic conditions and space expenditures naturally involve a certain degree of uncertainty. Projections of economic conditions from different econometric models may be expected to be different. In an appendix, we have formulated an alternative econometric model which may be used to provide alternative projections of economic conditions. At present, this alternative model has not yet been implemented for empirical analysis since its formulation is still very tentative. In addition to the uncertainty associated with the projection of economic conditions, the additional empirical equation used for the projection of space expenditures is subject to, perhaps, much greater uncertainty. The present formulation determines the level of space expenditures by its past level, the level of government expenditures in general, and the rate of inflation. This is, of course, not the only reasonable formulation. There is some evidence to suggest that other factors such as the rate of unemployment or other economic conditions may also determine the level of space expenditures.

In our micro-activity analysis, we have investigated the impact of space expenditures on various industries or groups of industries. Specifically, we have evaluated the impact of the reallocation of a $3 billion space expenditure to certain alternative uses in terms of the effects on the levels of production and employment. The empirical results have been obtained only by employing a simple-static input-output model, though in an appendix the feasibility of a dynamic input-output model has been considered. There are four alternative expenditures considered in this report. They include new construction, communication and transportation equipment, and medical and educational services, as well as research and development in general.

The impact of a reallocation of $3 billion from space expenditures to each of the four alternative uses was found to be relatively small, except for those industries which are directly affected. This is shown to be true both in terms of production levels and employment levels of various industries. In fact, except for those industries which are directly affected by the reallocation of $3 billion, almost no industry would be affected either beneficially or adversely by more than 1% of the 1970 production or employment level.

As to the impact on the industries which are directly affected by the reallocation of $3 billion in space expenditures, while it is true that ordnance and aircraft industries together would decrease their production by nearly $4 billion annually, it must also be recognized that the alternative industry would increase its production by more than $3 billion. Similarly, in terms of employment, while it is true that transportation equipment and ordnance industries would lose about 170 thousand man years of employment, it must also be recognized that the alternative industry would gain more or less the same level of employment, depending on its labor intensity.

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FOOTNOTES IN SECTION 7.2
ON MACRO ECONOMETRIC MODEL

1. This section is largely based on an earlier report, "A Macro Econometric Model for Projections of National Economy and Space Expenditure", Working Paper, MATHEMATICA, October 1971.

2. Nerlove summarized the features of twenty-five macro econometric models in [14], covering a wide range of annual and quarterly models.

3. A concise description of macro econometric models which provides many useful references can be found in Wallis [17].

4. Although five tax-transfer payment relationships were mentioned (p. 172), no empirical estimate of these relationships was reported.

5. The estimates given were obtained from the data for the post-World War II Years (1948-64). The estimates based on the entire sample period have a negative sign for the coefficient associated with corporate tax rate.

6. It may be more desirable to introduce a separate deflator for government purchases of goods and services as an exogenous variable.

FOOTNOTES IN SECTION 7.3 ON MICRO ACTIVITY ANALYSIS

1. An excellent introduction can be found, for example, in W. Baumol [1, Chs. 20 and 21] and Chenery and Clark [3].

Appendix 7A: An Alternative Macro-Econometric Model of the United States

A.1 Introductory

The purpose of this appendix is to provide a critical review of the macro-econometric model adopted in Chapter 7. The appendix is divided into three sections. In this section, several possible improvements are considered. In the next section, an alternative macro-econometric model which incorporates most of these modifications is presented. Finally, in the last section the linkage of the macro-econometric model with the micro-activity analysis, or input-output analysis, is indicated.

Previously, we have described how the well-know Klein-Goldberger model can be modified to incorporate a sub-model of the government sector. The modified model has been tested empirically by examining its simulation results for the period 1965-1970. These simulations pointed out a number of areas in which the model could be strengthened.

First, even if the equations of the model are unchanged they should at least be updated. The revisions of the national income accounts in 1965 were in some ways quite significant. Also, if the model is to predict it should be estimated with the most recent observations possible since the information contained in recent observations is likely to be more germane to the future. However, more than updating alone is needed.

Improved specification is needed for many of the equations. It must be remembered that the Klein-Goldberger model was a pioneering effort and the modifications incorporated in the version used here were relatively minor. Since this model was developed, the state of the art in econometric-model building has improved greatly. Thus, it is desirable to embody many innovations in the model in order to develop a better forecasting tool. Among the desirable innovations is an improved specification of the production function (6), which determines private employment. In particular, it should take explicit account of technological change and the capital stock.

The problem of inflation should be treated more adequately. In particular, several price deflators should be incorporated rather than an aggregate GNP deflator alone. Furthermore, an explicit treatment would seem to be one improvement over the implicit treatment of the Klein-Goldberger model.

Certainly federal government activities should be treated separately from those of state and local government. State and local government purchases of goods and services are approximately equal to those of the federal government and are growing at a much more rapid rate. Therefore it stands to reason that separation would improve our understanding of NASA's budgetary environment.

Improvement might also be possible through a more detailed treatment of monetary influences and profits. The present treatment of monetary influences is confined to the ratio of excess to required bank reserves and the Federal Reserve discount rate. This treatment has been fairly effective in the Wharton Economic Forecasting Unit's quarterly model as well as the Klein-Goldberger model. Improvement should be considered but does not seem to be as important as the other problems.

Corporate profits are treated as a residual in the Klein-Goldberger model. This specification could, and should be improved, but it is not clear that an inadequate specification of profits is too important to the remainder of the model. It does not seem as important as other problems and may improve as other portions of the model are improved.

Finally, more attention should be paid to the projection of exogenous variables. It seems likely that improvement will result if a wider variety of projection formulas are applied.

The above qualifications notwithstanding, we have applied the model to project the economy for the period 1971-1980, under certain restrictive assumptions. The results of two basic simulations for short-term and long-term projections have been discussed. Furthermore, the impact of alternative government policies, both expansionary and restrictive, were also examined. These results have also been used to project future expenditures for space research and technology. The resulting patterns of our dynamic simulations of the national economy in general, and space expenditures in particular, are not implausible. We have found that expenditures for space research and technology are perhaps determined not so much by the level of government expenditures in general as by the rate of inflation and its own previous year's expenditures. Therefore, in order to project the expenditures for space research and technology, we must be able to project not only the level of government expenditures, in general, but also the rate of inflation and possibly some other variables.

A.2 An Alternative Model

As seen from the previous discussion, the modified Klein-Goldberger model has a number of shortcomings which should be remedied in developing a practical tool for forecasting NASA's budgetary environment. A great deal has been accomplished in the past few years in constructing macro-econometric models, therefore it is not necessarily the best strategy to build from scratch. Rather, we recommend the development of a hybrid model which incorporates the strongest features of several models which have already been developed. However, the development of such a hybrid is not simply a matter of picking a collection of equations and calling the collection a model. If this were the case we would have adopted this strategy at the outset of our study. A considerable amount of thought is necessary on exactly what form the hybrid should take and how its component parts should fit together. The result of our work on this problem is the model which we recommend here. Since most of the equations have already appeared in other work, parameter estimation should be primarily a matter of updating the equations rather than seeking new theoretical development.

Data Sources

The endogenous and exogenous variables of the model are presented below. The sources of the data are given in parentheses. These sources are abbreviated as follows:

ERP — Economic Report of the President, 1971, Appendix C
SCB — Survey of Current Business, National Income Issues

BS	<u>Business Statistics</u>
P	J. Pechman, <u>Federal Tax Policy</u>, 1966, Brookings

Endogenous Variables

C	total personal consumption, 1958 dollars (ERP, C-2)
CPTF	corporate profit tax accruals, federal, current dollars (ERP, C-66)
D	capital consumption allowances, current dollars (ERP, C-13)
DEBT	gross federal debt, current dollars (ERP, C-64)
DEF	federal budget surplus or deficit, current dollars (ERP, C-64)
GF	federal government purchases of goods and services, 1958 dollars (ERP, C-2)
GG	federal expenditures on general government, current dollars (ERP, C-64)
H	stock of inventories, current dollars (ERP, C-42)
h	index of hours worked per week, 1958 = 1.00 (ERP, C-28)
I	investment in plant and equipment, 1958 dollars (ERP, C-2)
IBTF	indirect business tax liability, federal, current dollars (ERP, C-66)
IBTS	indirect business tax liability, state and local, current dollars (ERP, C-72)
I_m	imports, 1958 dollars (ERP, C-2)
IPF	interest payments, federal, current dollars (ERP, C-66)
K	capital stock, 1958 dollars (SCB, 4/70, all industries, constant cost 2 estimates)
K54	capital stock beginning in 1954, 1958 dollars (see K)
K62	capital stock beginning in 1962, 1958 dollars (see K)
N_g	government employees (ERP, C-27)
N_p	private wage and salary employees (ERP, C-27)
p	aggregate GNP deflator, 1958 = 1.00 (ERP, C-3)
P_c	corporate profits, current dollars (ERP, C-14)
pc	consumption deflator, 1958 = 1.00 (ERP, C-3)
p_g	deflator for government purchases of goods and services, 1958 = 1.00 (ERP, C-3)

PI	personal income, current dollars (ERP, C-17)
PITF	personal income tax revenues, federal, current dollars (ERP, C-66)
PITS	personal income tax revenues, state and local, current dollars (SCB)
p_p	private GNP deflator, 1958 = 1.00 (ERP, C-3)
R	investment in residential construction, 1958 dollars (ERP, C-2)
r	average yield on corporate bonds, Moody's percent (BS, SCB blue pages)
r_s	yield on prime commercial paper, 4-6 months, percent (ERP, C-57)
S_c	corporate savings, current dollars (ERP, C-13, C-14, C-66, C-72)
SICF	social insurance contributions, federal, current dollars (ERP, C-66)
TFE	total federal expenditures, current dollars (ERP, C-66)
TFR	total federal revenues, current dollars (ERP, C-66)
TRNF	transfer payments, federal, current dollars (ERP, C-66)
UFE	"uncontrollable" federal expenditures, current dollars (see eq. 29 below)
U	unemployment rate, percent (ERP, C-22)
W_f	federal wage bill, current dollars (SCB)
W_p	private wage bill, current dollars (SCB)
w_p	average annual earnings, private, current dollars (WP/hNp)
X	gross national product, 1958 dollars (ERP, C-2)
X_p	gross national product minus the government wage bill (GNP-WF-WS), 1958 dollars, (ERP, C-8)
Y	disposable personal income, 1958 dollars (ERP, C-15)
Π	total profits, current dollars (ERP, C-12)
Π_r	rental income and net interest, current dollars (ERP, C-12)

Exogenous Variables

CPTR	corporate profits tax rate, federal (P, A-3)
CPTS	corporate profits tax accruals, state and local, current dollars (ERP, C-72)
D67	a dummy variable equal to 1.00 for 1967 and beyond, 0.0 otherwise (no source necessary)

E	exports, 1958 dollars (ERP, C-2)
GS	government purchases of goods and services, state and local, 1958 dollars (ERP, C-2)
L	civilian labor force (ERP, C-22)
M	federally sponsored research and development, 1958 dollars (National Science Foundation)
NASA	expenditures of the National Aeronautics and Space Administration (Federal Budget)
NS	self-employed persons (ERP, C-22)
OTHER	"controllable" federal expenditures not including the National Aeronautics and Space Administration (Federal Budget)
PITR	"first-bracket" federal personal income tax rate (P, A-2)
p_m	import deflator, 1958 = 1.00 (ERP, C-3)
P65	population over age 65 (ERP, C-21)
r_d	average discount rate at Federal Reserve Banks (ERP, C-57)
R_e	year-end ratio of Federal Reserve System member banks' excess to required reserves (ERP, C-56)
r_g	interest rate on 3-month U. S. Treasury Bills (ERP, C-57)
RSOC	rate of employer plus employee contributions to federal social insurance (P, A-6)
T	annual trend (no source necessary)
w_g	annual average earnings of government employees (W_g/N_g)
W_s	wage bill of state and local government employees, current dollars (SCB)

The Equations of the Model

The recommended model is basically a combination of the Klein-Goldberger model [4] and the model by Lester Thurow [5]. However, other investigations such as the Wharton Economic Forecasting Unit's quarterly model [3] and the Brookings-SSRC model [1] and [2] have also contributed to the recommended formulation. The principal work involving new results concerns the production function and most federal revenue and expenditure equations -- (15), (23), (26), (27), (28), (37), (39) and (42). The remainder of the equations are either borrowed directly from the Klein-Goldberger, Thurow or Wharton models, or are close enough to existing formulations that little or no trouble is expected in their estimation. In the equations which follow, those which have been borrowed from the Klein-Goldberger model are indicated by (K-G), from the Thurow model by (Thurow) and from the Wharton model by (Wharton).

Consumption function

(1) $C = a_0 + a_1 Y_{-1} + a_2 \Delta Y + a_3 C_{-1}$ (Thurow)

Investment in residential construction

(2) $R = a_0 + a_1 Y - a_2 r_{-1} + a_3 R_{-1}$ (K-G)

Investment in plant and equipment

(3) $I = a_0 + a_1 X_p + a_2 (\frac{1}{u}) + a_3 K_{-1} + a_4 I_{-1}$

Investment in inventories

(4) $\Delta H = a_0 + a_1 X_p - a_2 \left(H/p_p\right)_{-1} + a_3 (\frac{1}{u}) + a_4 t$ (Thurow)

Import demand function

(5) $I_m = a_0 + a_1 \Delta (p_m/p) + a_2 Y_{-1} + a_3 \Delta Y$ (Thurow)

Production function

(6) $X_p = a_0 M^{a1} K^{a2} N_p^{a3}$

Hours worked function

(7) $h = a_0 + a_1 \Delta w_p + a_2 (L - N_p - N_g - N_s)$ (K-G)

Interest rates

(8) $r_s = a_0 + a_1 r_d + a_2 R_{e-1}$

(9) $r = a_0 + a_1 r_s + a_2 r_{-1}$ (K-G)

Corporate saving function

(10) $pS_c = a_0 + a_1 (pP_c - T_c) - a_2 (pP_c - T_c - pS_c)_{-1}$ (K-G)

Non-corporate income equation

(11) $p(\pi - P_c) = a_0 + a_1 p_p X_p + a_2 [p(\pi - P_c)]_{-1}$ (K-G)

Rentier income equation

(12) $p_p \Pi_r = a_0 + a_1 p_p (I + R) - a_2 (r - r_{-1}) + a_3 (p_p \Pi r)_{-1}$ (K-G)

Depreciation equation

(13) $D/p_p = a_0 + a_1 K_{t-1} + a_2 K^{54}_{t-1} + a_3 K^{62}_{t-1}$ (Thurow)

Federal corporate profits tax

(14) $CPTF = A_0 + a_1 [CPTR \cdot P_c]$ (Thurow)

Federal indirect business tax

(15) $IBTF = a_0 + a_1 X_p + a_2 (p_c C) + a_3 IBTF_{-1}$

State and local indirect business taxes

(16) $IBTS = a_0 + a_1 X_p$ (Thurow)

Definition of real GNP

(17) $X = C + I + R + \Delta H + G_f + G_s + E - I_m$

Federal personal taxes

(18) $PITF = a_0 + a_1 (PITR \cdot PI)$ (Thurow)

State and local personal taxes

(19) $PITS = a_0 + a_1 PI - a_2 t + a_3 PITS_{-1}$ (Thurow)

National income - national product identity

(20) $pY = pX - D - IBTS - IBTF - pS_c - CPTF - CPTS - PITF - PITS = PI - PITF - PITS$

Definition of profits

(21) $p\Pi = pX_p - D - IBTS - IBTF - pW_p - p \Pi r$

Private wage bill

(22) $W_p = hw_p N_p$

Contributions to federal social insurance

(23) $SICF = e^{a_0} RSOC^{a_1} W_p^{a_2} W_g^{a_3}$

Total federal revenues

(24) $TFR = PITF + CPTF + IBTF + SICF$

Federal interest payments

(25) $IPF = a_0 + a_1 (r_g \cdot DEBT) + a_2 IPF_{-1}$

Federal debt

(26) $\Delta DEBT = a_0 + a_1 DEF$

General federal government expenditures

(27) $GG = a_0 + a_1 TFE$

Federal government transfer payments

(28) $TRNF = a_0 + a_1 P65 + a_2 (L - N_p - N_g - N_s) + a_3 pX + a_4 P65 \cdot D67$

"Uncontrollable" federal expenditures

(29) $UFE = IPF + GG + TRNF$

Total federal expenditure

(30) $TFE = UFE + NASA + OTHER$

Federal budget

(31) $TFR = TFE + DEF$

Private GNP deflator

(32) $\Delta p_p = a_0 + a_1 \left(\frac{w_p N_p}{X_p} \right) + a_2 \left(\frac{1}{u} \right) + a_3 DK + a_4 p_{p-1}$ (Wharton)

Government GNP deflator

(33) $\Delta p_g = a_0 + a_1 \left(\frac{w_g}{w_{g(1958)}} \right)$

Aggregate GNP deflator

(34) $p = \frac{p_p X_p + W_g}{X_p + W_g / p_g}$

Consumption deflator

(35) $\Delta p_c = a_0 + a_1 \Delta p_p + a_2 t$

Private wage rate

(36) $\Delta w_p = a_0 + a_1 \Delta p_c + a_2 (\frac{1}{u}) + a_3 \Delta w_{p-1}$

Government wage rate

(37) $\Delta w_g = a_0 + a_1 \Delta p_c + a_2 \Delta w_p + a_3 \Delta w_{g-1}$

Private GNP

(38) $X_p = X - W_g/p_g$

Federal government wage bill (= gross product originating in federal government)

(39) $W_f = a_0 + a_1 \text{ TFE}$

Total government wage bill

(40) $W_g = W_f + W_s$

Total government employment

(41) $N_g = W_g/w_g$

Federal government purchases of goods and services

(42) $p_g G_f = a_0 + a_1 \text{ TFE}$

Unemployment rate

(43) $U = (L - NP - NG) \times \frac{1}{L}$

Capital stock identity

(44) $K = K_{-1} + I - D$

This model, while embodying much of the original Klein-Goldberger structure, does appear to have the potential to provide more accurate and more meaningful forecasts. In the previous section, a number of improvements were called for. Improvement in the production function is to be found in equation (6). This is basically a Cobb-Douglas production function with one major change -- the incorporation of a variable representing government-sponsored research and development to capture the influence of technological change. If the initial promise of this work does not materialize, a more traditional production function, such as that used by Thurow, can be used instead.

A second problem discussed was that of inflation. The treatment in the recommended model is somewhat similar to that of the Wharton model, in that different price level deflators are included for different sectors and that the treatment of price change is much more explicit than in the Klein-Goldberger model. This should result in a much more accurate characterization of the problem of inflation.

The third major change is the specification of the government sector. The recommended model improves specification in two ways: (1) it separates federal from state and local expenditures and (2) it models the specific "controllable" expenditures from which NASA's budgets must come.

Taken as a whole these three major innovations, plus several of lesser impact, should enhance both the forecasting accuracy and the usefulness of the macro-econometric approach to a significant extent.

A. 3 Linkages with the Input-Output Model

It would be highly desirable to link the macro-econometric model to the input-output model. The two types of approaches have different strengths and weaknesses. By linking them, important weaknesses could be remedied while the strengths could be retained. In particular, the macro-econometric model has virtually no inter-industry information which is critical in determining NASA's impact on the rest of the economy. On the other hand, the input-output model contains inter-industry relationships but does not, by itself, generate forecasts. Therefore, it would seem appropriate to attempt to link the models so that the forecasting characteristics of the macro-econometric model could be combined.

The specific details of how to bring about this meshing have not yet been investigated, but it does seem likely that the most promising approach would be to disaggregate the forecasts of final demand of the macro-econometric model (consumption, plant and equipment investment, residential construction, inventory investment, exports, imports and government pur-

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chases of goods and services) into the elements of the final-demand vectors of the input-output model. Thus, with forecasts of the final demand vectors available, the input-output model could be used to predict inter-industry transactions. Of course, the question that this approach raises is how to disaggregate the final-demand forecasts of the macro-economic model. Theoretically, the best approach would be to build the required detail into the macro-economic framework. This, however, does not appear to be practical. Probably the best strategy would be to first make aggregate forecasts and then disaggregate the results.

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Appendix 7B: A Closed Dynamic Model for the Analysis Of Production and Consumption Activities

B.1 Introductory

In the text of Chapter 7, the micro-activity analysis was briefly reviewed. The empirical analysis in that chapter was based only on a simple static model. The purpose of this appendix is to develop a new model so that the analysis can be based on a more realistic dynamic model. Furthermore, in addition to an analysis of production activites, the model is formulated to cover consumption activities as well. The model has been developed primarily with empirical applications in mind. The results reported here, however, are limited to theoretical formulation.

The major purposes of the present appendix are twofold: first, to develop an analytical framework for evaluating the impact of a change in production technology or consumption preference; and second, to examine the meaning of a social rate of discount, the magnitude of which may be empirically observable. So far our empirical activity analysis has been confined to an application of an open-static-activity analysis. The analysis of the impact of space expenditures on the national economy, as reported in the text of Chapter 7, has been limited to the impact of a change in consumption preference. The consumption activities have been treated as exogenous. Therefore, no attempt has been made to explain how the levels of consumption are determined. In the closed dynamic model of activity analysis formulated in this appendix, consumption activities are regarded as endogenous. Such a model can be used to evaluate the impact of space expenditures and provide alternative time-paths of economic growth. The issue of the social rate of discount, as demonstrated in our previous chapters, is extremely important in evaluating alternative Space Transportation Systems. The discussion in this appendix provides some insight as to how an appropriate social rate of discount may be chosen for government decision-making.

Although many familiar early works of activity analysis, both in static and dynamic frameworks, were formulated in the form of a closed model, more recent literature of theoretical investigations and empirical applications tends to focus on developing a possibly more realistic open model. For example, the celebrated von Neumann model has been opened by J. Kemeny, O. Morgenstern, and G. Thompson [3] and more recently by O. Morgenstern and G. Thompson [8], [9] and [10] in their interesting theoretical contributions. Most recent works on more practical input-output analyses also deal largely with an open model where consumption activities are treated as exogenous. This historical evolution is clearly reflected in W. Leontief's own works on input-output systems, witnessing his recent contributions to an open dynamic system of economic growth, [5] and [6]. While it is clearly unsatisfactory to treat consumption activities equally as production activities as was done in many early closed models, it is perhaps also undesirable to leave consumption activities entirely unexplained as has been done in most recent open models. The major purpose of this paper is to formulate a closed model by expanding the open-dynamic Leontief model to incorporate a demand-oriented consumption-preference function, in addition to the original supply-oriented production-technology function. The selection of the open-dynamic Leontief model as our basis for extension is partly due to its familiarity to many economists, but mostly due to our emphasis on feasibility for empirical applications.

There are several important implications of the closed dynamic model which will be considered in this appendix. Above all, our model will reveal the possible impact of production technology and consumption preference on the growth patterns of production and consumption activities. Furthermore, it will shed some light on the controversy of social rates of discount. Following this introduction, the plan of the present paper is as follows: in Section 1, the closed dynamic model of production and consumption will be formulated and then "normalized" to take the standard form of a system of first-order homogeneous difference equations.[1] In Section 2, we shall consider the quantity system and its implications for the flow and stock requirements of production activities and the rigidity and income expectation of consumption activities. In Section 3, we shall being with a discussion of the price system and examine its implication for social rates of return to investment and saving. Finally, in the last section, in order to point out the possibility of further modifications or refinements, we shall offer some remarks on our model emphasizing its relations to some other existing models. Most significant conclusions of the present paper will also be recapitulated.

B.2 The Closed-Dynamic Model and Its Normalization

In the open-dynamic model originally developed by Leontief [7] and further investigated by many others, as well as Leontief himself more recently [5] [6], consumption activities are treated as exogenous. The model deals only with production technology and thus completely ignores consumption preference. The present paper attempts to formulate a closed-dynamic model by treating the original Leontief open-dynamic model as a sub-system of a much larger system which includes both production technology and consumption preference explicitly. The major difference between the present expanded-closed model and either the earlier original closed models or more recent open models is an explicit consideration of consumption behavior. The consumption activities are neither merged with production activities without any distinction nor regarded as entirely exogenous.

Since the Leontief open-dynamic model is chosen as the basis of our expanded closed-dynamic model, it is convenient to follow his notation whenever possible. In fact, this means that in the specification of production technology, we shall be following precisely his specification and notation. On the other hand, in the specification of consumption preference, some additional notation will be necessary, though it is not likely to be numerous. The proposed closed-dynamic model to be discussed throughout the present appendix consists of the following two first-order-vector difference equations (or two systems of equations):

$$(1) \qquad (I - A_{t-1})\, X_{t-1} = B_t\, (X_t - X_{t-1}) + C_{t-1}$$

and

$$(2) \qquad C_t = \Gamma_t\, [(I - A_t)\, X_t] + L_t\, C_{t-1}$$

where X_t and C_t are n-element column vectors of production and consumption of n industries or activities at the t time period. The n by n square matrices A_t and B_t represent production technology and are called "flow coefficients" and "stock coefficients" respectively. Similarly, the n by n square matrices Γ_t and L_t represent consumption preference and, for the lack of establishing terminologies, may be called "current propensities" and "lagged propensities" of consumption. For convenience, we shall designate equation (1) as the production function, and equation (2) as the consumption function.

The production function (1) is exactly the same as the Leontief open-dynamic model, except the time subscript t has been lagged for one period to conform with the consumption function (2). The equation simply states that the net output of any time period of all commodities are divided into either capital accumulation or final consumption.[2] Our consumption function (2) is also fairly straightforward. It simply states that the current levels of consumption of all commodities are determined by the current levels of net output and the past levels of consumption of all commodities.[3] As is familiar in demand analyses or usual consumption studies, the specification of the consumption function (2) may be based on the considerations of income expectation or rigidity in consumption pattern.

Although, in general the production technology A_t and B_t as well as the consumption preference Γ_t and L_t may be expected to vary from one time period to the other, any change in these matrices would usually be very gradual. Notice that flow coefficients of different time periods, i.e., A_t and A_{t-1}, appear in the production function (1) and the consumption function (2). For convenience, without losing very much of realism, we shall assume that flow coefficients of the successive time periods are identical, i.e., $A_t = A_{t-1}$. Furthermore, since we shall not be concerned with problems of changes in production technology or consumption preference, we shall from now on drop the time subscripts appearing in A_t, B_t, Γ_t and L_t.

The production function (1) and the consumption function (2), when considered separately, each represent a first-order non-honogeneous vector-difference equation (or a system of n equations). Together they constitute a system of two vector-difference equations (or a system of 2n equations). The closed dynamic model represented by the production function (1) and the consumption function (2) together can be rewritten as

$$(3) \qquad \begin{bmatrix} X_{t-1} \\ \hdashline C_{t-1} \end{bmatrix} = \left[\begin{array}{c:c} A & I \\ \hdashline -\Gamma(I-A) & I+(I-L) \end{array}\right] \begin{bmatrix} X_{t-1} \\ \hdashline C_{t-1} \end{bmatrix} + \left[\begin{array}{c:c} B & 0 \\ \hdashline -\Gamma(I-A) & I \end{array}\right] \begin{bmatrix} X_t - X_{t-1} \\ \hdashline C_t - C_{t-1} \end{bmatrix}$$

or, after advancing the time subscript for one period, in a more conventional form as

$$(4) \qquad \begin{bmatrix} X_t \\ \hdashline C_t \end{bmatrix} = \left[\begin{array}{c:c} A & I \\ \hdashline -\Gamma(I-A) & I + (I-L) \end{array}\right] \begin{bmatrix} X_t \\ \hdashline C_t \end{bmatrix} + \left[\begin{array}{c:c} B & 0 \\ \hdashline -\Gamma(I-A) & I \end{array}\right] \begin{bmatrix} \Delta X_t \\ \hdashline \Delta C_t \end{bmatrix}$$

where $\Delta X_t = X_{t+1} - X_t$ and $\Delta C_t = C_{t+1} - C_t$.

For convenience, equation (4), in turn, may be rewritten in a more compact form as

$$(5) \qquad Z_t = G \; Z_t + H \, \Delta \, Z_t$$

where the notation is evident from a comparison between (4) and (5). Notice that the closed-dynamic model (4) or (5) is formally the same as an early Leontief closed-dynamic model where consumption in equation (1) is assumed to be a zero vector and the consumption function (2) is ignored entirely. The properties of such a closed-dynamic model have been extensively studied. In particular, we may point out that the closed-dynamic model (4) or (5) is capable of balanced growth if the matrix appearing as the coefficients of the first term of (4) or (5) satisfies Hawkins-Simons conditions [1, pp. 220-222]. There exists, however, a problem of "casual indeterminacy", since the path of balanced growth need not be stable [2]. Although such a problem has a considerable theoretical interest, we shall not discuss it any further in view of our emphasis on the feasibility of empirical applications.

It can be verified that the closed-dynamic model (4) can be normalized into a form of standard first-order homogeneous vector difference equation as

$$(6) \qquad \begin{bmatrix} X_t \\ \hdashline C_t \end{bmatrix} = \left[\begin{array}{c:c} B^{-1}(I-A+B) & B^{-1} \\ \hdashline \Gamma(I-A)\, B^{-1}(I-A+B) & \Gamma(I-A)\, B^{-1}+L \end{array}\right] \begin{bmatrix} X_{t-1} \\ \hdashline C_{t-1} \end{bmatrix}$$

or more compactly as

$$(7) \qquad Z_t = [I+H^{-1}(I-G)]\ Z_{t-1} = M\ Z_{t-1}$$

where the definitions of Z_t and M are evident from a comparison of equations (6) and (7), the matrices G and H have been defined in (5).

B.3 The Quantity System and Growth Rates of Production and Consumption

Earlier we pointed out that the closed-dynamic model (4) or (5), though it is capable of balanced growth, may be unstable. Consequently, rather than concentrating on the nature of balanced growth, it is perhaps more fruitful to study the time path of possibly unbalanced growth. The task of this section is to demonstrate that, for a given production technology and consumption preference, the closed-dynamic model (4) or (5) implies constant growth rates of production and consumption (so long as they remain positive). These growth rates need not be the same among various production or consumption activities. In fact, they may be expected to be different from one activity to another. Furthermore, we shall show that according to our model the stock coefficients can be inferred from the knowledge of the flow coefficients once the growth rates of production and the pattern of consumption are known. This result is of considerable importance, since the paucity of information on the stock coefficients has long been a major obstacle to empirical applications of dynamic activity analyses.

Let us begin with a consideration of the growth patterns of production and consumption activities. From the normalized form of our closed dynamic model (6) or (7), the growth pattern can be easily seen as

$$(8) \qquad \left[\begin{array}{c} X_{t+h} \\ \hdashline C_{t+h} \end{array}\right] = \left[\begin{array}{c:c} B^{-1}(I-A+B) & B^{-1} \\ \hdashline \Gamma(I-A)\ B^{-1}(I-A+B) & \Gamma(I-A)\ B^{-1}+L \end{array}\right]^h \left[\begin{array}{c} X_t \\ \hdashline C_t \end{array}\right]$$

or more compactly as

$$(9) \qquad Z_{t+h} = [I+H^{-1}(I-G)]^h\ Z_t = M^h\ Z_t.$$

It is clear that the growth pattern is determined entirely by the characters of production technology A and B and consumption preference Γ and L appearing in (8), which are denoted ~~simply~~ as M in (9).

Alternative to the solution (8) or (9), the closed-dynamic system (4) or (5) can be solved by a simple process of elimination to obtain some empirically useful relations. We may proceed by noticing that the solution of the consumption function can be written as

$$(10) \qquad C_t = L^t C_0 + (I-L^t)(I-L)^{-1} \Gamma (I-A) X_t$$

which may be substituted into the production function (1) to obtain

$$(11) \qquad B(\Delta X_t) = \left\{[I - (I-L)^{-1} \Gamma](I-A)\right\} X_t$$

if we assume $L^t \to 0$ as $t \to \infty$. Collecting similar relations of (11) for n different time periods, we may write

$$(12) \qquad B(\Delta X) = \left\{[I - (I-L)^{-1} \Gamma](I-A)\right\} X$$

where $\Delta X = [\Delta X_1 \; \Delta X_2 \cdots\cdots \Delta X_n]$ and $X = [X_1 \; X_2 \cdots\cdots X_n]$, which implies

$$(13) \qquad B = \left\{[I - (I-L)^{-1} \Gamma](I - A)\right\} R_x^{-1}$$

where R_x is, in a diagonal form, the growth rates of production activities. Equation (13) shows that stock coefficient B can be inferred from the knowledge of flow coefficients A and consumption preference, including current and lagged propensities Γ and L. The same equation (13) can be used for other purposes; for example, to infer the consumption preference Γ or L when other information is available. Finally, by eliminating X_t instead of C_t, we can also arrive at an expression similar to (13) as

$$(14) \qquad B = \left\{[I - (I-L)^{-1} \Gamma](I-A)\right\} \left(\frac{1}{r_c}\right)$$

where r_c (a scalar) is the balanced growth rate of consumption activities, if it exists. Notice that in (14) we have assumed that all consumption activities grow at the same constant rate r_c. In this special case, all production activities should also grow at the same constant rate $r_x = r_c$, so that (13) and (14) become identical.

By rearranging (13) and (14) slightly, we can express the growth rates of production activities and consumption activities explicitly as

$$(15) \qquad R_x = \left\{[I - (I-L)^{-1} \Gamma](I-A)\right\} B^{-1}$$

and

$$(16)\qquad R_c = \left\{[I - (I-L)^{-1}\,\Gamma]\,(I-A)\right\}\,B^{-1}$$

where $R_c = r_c I$. Notice that in arriving at (15), we did not assume the same growth rate for all production activities. In arriving at (16), we assumed, however, that the growth rates of all consumption activities are the same in order to obtain such a simple expression.

B.4 The Price System and Social Rates of Return to Investment and Saving

In order to study the price system of the closed-dynamic model (4) or (5), we may follow Solow [12] and assume that there is no uncertainty regarding capital gains obtainable either directly through investment activities or indirectly through consumption activities. Therefore, the price system corresponding to the quantity system (4) may be written as[4]

$$(17)\qquad P(t) = (I + S)\left\{I + [(I - G)\,H^{-1}]'\right\}^{-1} P(t - 1)$$

where P(t) and P(t-1) are 2n-element vectors of n commodity prices which may be either factor prices or market prices (corresponding to production and consumption activities). G and H are 2n by 2n matrices defined previously in (5), and S represents the social rates of return to investment and consumption, expressed in the form of a diagonal matrix. The solution to (17) can be written as

$$(18)\qquad P(t + h) = (I + S)^h\left\{I + [(I - G)\,H^{-1}]'\right\}^{-h} P(t)$$

which gives the time path of price patterns. This expression turns out to be quite complicated in terms of the original matrices A, B, Γ and L. For convenience, we may simply write (17) in an implicit form as

$$(19)\qquad \begin{Bmatrix} P_f(t) \\ \hline P_m(t) \end{Bmatrix} = \begin{Bmatrix} (I+S_x) & 0 \\ 0 & (I+S_c) \end{Bmatrix} \begin{Bmatrix} \Phi_{11} & \Phi_{12} \\ \Phi_{21} & \Phi_{22} \end{Bmatrix} \begin{Bmatrix} P_f\,(t-1) \\ \hline P_m\,(t-1) \end{Bmatrix}$$

where $p_f(t)$ and $p_m(t)$ are n-element column vectors of factor prices and market prices respectively, S_x and S_c are n-element diagonal sub-matrices of social rates of return to investment and saving respectively, and Φ_{ij} are the appropriate n by n sub-matrices of the inverse of the matrix appearing inside the brackets of (17)[5].

To gain some further insight into the relationship between social rates of return to investment and saving, we may examine (19) more explicitly. The solution of (19) for factor prices and market prices can be given as

(20) $$P_f(t) = (I+S_x)^t \left[\Phi_{11}{}^t P_f(0) + (I-\Phi_{11}{}^t)(I-\Phi_{11})^{-1} \Phi_{12} P_m(t)\right]$$

and

(21) $$P_m(t) = (I+S_c)^t \left[\Phi_{21}{}^t P_m(0) + (I-\Phi_{21}{}^t)(I-\Phi_{21})^{-1} \Phi_{22} P_f(t)\right].$$

By substituting (21) into (20) or vice versa, we obtain the relationship between S_x and S_c in an implicit form. Letting t=1, in an extremely simplified situation where $\Phi_{11} = \Phi_{21} = 0$, we have

(22) $$S_x = \Phi_{22}(I+S_c)^{-1}\Phi_{12} - I.$$

In general, social rates of return to investment and saving are related in a much more complicated form, which is difficult to express explicitly. This result merely indicates that social rates of return to investment and saving are necessarily related to one another in some specific manner. More useful results may be obtained by analyzing some other less restrictive situations. The special cases where L=0 and Γ=0 are worthy of further examination.

Assuming either Γ=0 or L=0, it can be verified that, from (19) we obtain

(23) $$P_f(t) = (I+S_x)\, \Phi_{11}\, P_f(t-1)$$

where $\Phi_{11} = [I + (B^{-1})' \;(I-A)']^{-1}$ which implies

(24) $$\Delta P_f = [(I+S_x)\, \Phi_{11} - I]\, P_f$$

where $\Delta P_f = [\Delta P_{f1} \; \Delta P_{f2} \cdots\cdots \Delta P_{fn}]$ and $[P_f = P_{f1} \; P_{f2} \cdots\cdots P_{fn}]$ are n by n square matrices of factor prices with numerical subscripts indicating different time periods. From (24), we obtain the rates of return to investment as

$$S_x = (D_x + I) \phi_{11}^{-1} - I \tag{25}$$

where D_x, expressed in a diagonal form, represents rates of inflation of factor prices of n commodities. As to the rates of return to saving S_c, very little concrete results seem to be obtainable even if $\Gamma = 0$ or $L = 0$. One may surmise that they should be very close to the rates of investment S_x.

Throughout the preceding discussion we have allowed social rates of return to investment and saving to be different for each production or consumption activity. The reasons for their being different may be due to risk aversion or indivisibility, etc. Conceptually, it is quite reasonable to define the rate of return to investment as the lowest rate among S_x, and the rate of return to saving as the lowest rate among S_c. Furthermore, it is also reasonable to define the social rate of return to investment <u>and</u> saving as the lowest among both S_x and S_c.

B.5 Remarks and Conclusions

There are several distinct features of the closed-dynamic model considered in this paper. The model assumes that all n commodities can be used as <u>both</u> consumption goods <u>and</u> capital goods. Thus the matrix M in equation (7) is of size 2n by 2n with full rank. On the other hand, it is possible to assume that all n commodities can be used only as <u>either</u> consumption goods <u>or</u> capital goods, as in [11, Ch. III]. Practically, however, some intermediate situation is perhaps the most realistic. An important issue which was not considered explicitly in our model is the question of labor employment. One way of dealing with this problem is to introduce labor and earning explicitly into the consumption function, as in [11, Ch. IV]. We have considered only a simple situation where only one technology is available at all times. Therefore, no question of alternative techniques or technological progress has been examined.

The closed-dynamic model considered in the present appendix has been introduced to analyze the interaction between production technology and consumption preference. By considering both the production and consumption sides, our model is neither supply-oriented nor demand-oriented. It is an equilibrium-oriented dynamic system. In the preceding sections, we have explicitly considered the time paths of both the quantity system and the price system. In both cases, not only production activities but also consumption activities are examined explicitly. Furthermore, in line with our emphasis on empirical implications, we have studied a few practical problems. These include the inference about capital coefficients based on usually available data of production and consumption, and the implication for social rates of return to investment and saving. Some useful results have been explicitly derived for empirical verification.

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FOOTNOTES IN APPENDIX 7B

1. For an example of the usage of the term "normalized system" in this sense, see [11, p. 109]. It may be noted that a "normalized system" is equivalent to the "reduced form" of a system of structural equations in the econometric literature.

2. The Leontief open dynamic model is well known. For a discussion of this model, see, for example, [2] and [7].

3. Alternative specifications of consumption function may be found in [4, pp. 160-164] and [11, pp. 107-109].

4. We have adopted a slightly different convention in this section for the subscript indicating time periods in order to handle double subscripts, which will appear later somewhat more conveniently.

5. The following result can be verified by the technique of matrix inversion by partitioning:

$$\phi_{11} = M_{11}^{-1} [I - M_{12}] \phi_{21}$$

$$\phi_{12} = -M_{11}^{-1} M_{12} \phi_{22}$$

$$\phi_{21} = \phi_{22} M_{11}^{-1}$$

and

$$\phi_{22} = L' + M_{11}^{-1}$$

where,

$$M_{11} = I + (B^{-1})' (I - A)' (I - \Gamma)'$$

and M

$$M_{12} = (B^{-1})' (I - A)' \Gamma' L'.$$

CHAPTER 8.0

SUMMARY OF RESULTS OF COST-EFFECTIVENESS ANALYSES

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CHAPTER 8.0

SUMMARY OF RESULTS OF COST-EFFECTIVENESS ANALYSES

8.1 Introduction

This chapter contains a review of the cost-effectiveness analyses performed by MATHEMATICA of the New Space Transportation System over the period from July through December, 1971. The results reflect final Aerospace and Lockheed data, and data provided by NASA and the Shuttle contractors on the alternative shuttle configurations.

Over the intervening months since May, 1971, new developments have arisen, in particular, explicit annual and total funding constraints imposed upon a shuttle development program, that have required NASA to study in great detail alternative shuttle configurations to the two-stage fully reusable system. These include designs offered by McDonnell Douglas, North American Rockwell, Grumman, and Lockheed and include an orbiter with a reusable flyback SIC booster, a stage and one-half orbiter, a series burn large pressure fed booster, and thrust assisted orbiter shuttles (TAOS) including twin pressure fed and solid rocket motor versions. All of these concepts imply a trade-off between non-recurring costs (RDT&E and Fleet Investment) and cost per flight, i.e., an increase in cost per flight up to $10 million for lowered non-recurring costs <u>holding capability constant.</u> With the data bases provided by the Aerospace Corporation and LMSC and the estimates on non-recurring and recurring costs provided by the contractors, MATHEMATICA has performed cost-effectiveness analyses -- on an equal capability basis -- of these concepts consistent with the analyses of the two-stage fully reusable system studied through May, 1971. This effort is presented in Section 8.2.

In Section 8.3, two mathematical expressions are offered, expressing the present value of allowable non-recurring cost evaluated at 10% discount of a shuttle with full payload capability -- the ability to launch 65,000 pounds due east, and 40,000 pounds north polar -- as a function of the activity level (the number of shuttle flights over the 1979 - 1990 period), the payload effects parameters (RDT&E, unit investment, refurbishment) and the shuttle incremental launch costs (users' fee) for data bases including and excluding certain DoD missions. Using these expressions it is possible to obtain estimates of the effect of these parameters on the allowable non-recurring costs and determine the Economic Trade-Off Function presented in Chapter 3. Appendix 8-A contains life-cycle cost summary data for the configurations examined and the cost-effectiveness analysis on an equal capability basis.

8.2 Cost-Effectiveness Analyses of Alternative Space Shuttle Configurations

This section contains the summary of the equal capability cost-effectiveness analysis of approximately 50 Space Shuttle configurations and mission model scenarios. The estimates have been drawn from two data bases (1) including the DoD support missions representing 624 shuttle flights and (2) excluding the DoD support missions representing 514 shuttle flights. Data for these analyses on the payload side come from the final reports of LMSC and the Aerospace Corporation; for the shuttle configurations' non-recurring cost they come from the contractors, NASA, and the Aerospace Corporation.[1] The non-recurring cost data for the alternative configurations in this section are those generated through September, 1971. The latest data, generated during November and December, 1971, appear in Section 8.3 where the derivation of the economic trade-off line that was presented theoretically in Chapter 3.0 is given.

Contained in Table 8.1 is a summary of the equal capability analyses at the 10% discount rate for the two-stage fully reusable shuttle based upon 624 shuttle flights, and interim Aerospace data. Scenario 100 represents the nominal values for Case C (a "best" payload mix and 1979 tug IOC).

The allowable non-recurring cost, the maximum expenditures that can be incurred over the non-recurring cost phase of the two-stage shuttle for it to be cost effective at 10%, is $15.3 billion for Scenario 100. Application of the scenario analyses to these data indicates a range in

Table 8. 1

Summary of Economic Analysis:

Two-Stage Fully Reusable Shuttle[1]

September 1971

Scenario	Description	Nonrecurring Cost[2] (Billions 1970 $)	Shuttle Flights	Allowable Nonrecurring[3] (Billions 1970 $)
100	Baseline Case C[4]	14. 5	624	15. 3
101	OSSA reduced by 25%		565	14. 4
102	OSSA and OMSF reduced by 50%		464	12. 0
103	102 with DOD increased by 50%		568	15. 5
104	102 with DOD doubled		681	18. 6
105	102 with DOD reduced by 25%		403	10. 8
106	102 with Non-NASA applications increased by 50%		510	13. 0
107	102 with Non-NASA applications doubled		563	13. 6
108	102 with Non-NASA applications tripled		662	14. 7
109	Baseline Case C_1[5]		616	14. 7
110	109 with OSSA and OMSF reduced by 50%		457	12. 0
111	Baseline Case C_3[6]		618	14. 3
112	111 with OSSA and OMSF reduced by 50%		457	11. 7

1. Based upon interim Aerospace Data and 624 flights with full DOD model.
2. Includes Space Tug and Western Test Range.
3. Based upon a 10% discount rate.
4. 1979 Tug with "best" payload mix.
5. 1979 Tug with baseline payloads adapted for reuse.
6. 1985 Tug with "best" payload mix.
7. It is possible that a smaller fleet could accommodate the scenarios of relatively low traffic rates.

Table 8.2

Summary of Economic Analyses, of Alternative Configurations[1]

September, 1971 (1)

Scenario	Description	Nonrecurring Cost[2] (Billions 1970 $)	Allowable Non-recurring Cost (Billions 1970 $)
200	Grumman Two-Stage[4], 1979 FOC	9.8	15.1
201	Grumman RSIC, 1979 FOC	8.8	15.5
202	Grumman RSIC, 1982 FOC	8.8	13.4
203	Grumman RSIC, 1983 FOC	9.2	13.4
204	Grumman TAHO, 1979 FOC	6.4	12.7
205	MCDC RATO, 1979 FOC	6.6	13.2
206	MCDC IVC, 1979 FOC	8.3	13.8
207	MCDC HO/1 1983 FOC	12.3	14.1
208	MCDC Two-Stage[6], 1979 FOC	12.2	15.7
209	Internal NASA Two-Stage, 1979 FOC	10.1	15.5
210	Internal NASA Two-Stage, 1979 FOC, 1985 Tng.	10.4	15.4
211	Internal NASA Two-Stage, 1985 IOC	10.5	13.5
212	Internal NASA Two-Stage Phased Development 1985 IOC	11.7	10.9
213	Internal NASA Phased Minitech, 1985 IOC	10.2	11.5

1. Based upon interim Aerospace, NASA, and contractor data and 624 Shuttle -Flight Mission Model.
2. Includes cost of Space Tug and Western Test Range.
3. Based upon a 10 percent discount rate.
4. External hydrogen tanks on orbiter.
5. FOC is "Full Operating Capability"
6. Two-Stage Shuttle.

Table 8.3

Summary of Economic Analyses of Alternative Configurations[1]

September 1971 (2)

Scenario	Description	Nonrecurring Cost[2] (Billions 1970 $)	Allowable Non-recurring Cost[3] (Billions 1970 $)
300	Grumman Two-Stage[4], 1979 IOC	9.8	11.0
301	MCDC Two-Stage	12.2	11.4
302	Internal NASA Two-Stage, 1979 IOC	10.1	9.9
303	LMSC Stage & 1/2, 1979 IOC	7.9	10.5
304	RATO I/II, FOC 1979	7.4	12.0
305	Grumman TAHO, 1979 IOC	6.4	8.7
306	Grumman RSIC, 1979 FOC	8.8	11.3
307	MCDC RATO, 1979 FOC	6.6	9.0
308	MCDC IVC, 1979 FOC	8.3	9.5

1. Based upon Aerospace, NASA, and contractor data and 514 Shuttle-Flight Mission Model.
2. Includes Space Tug and Western Test Range.
3. Based upon a 10% discount rate.
4. External hydrogen tanks on orbiter.

Table 8.4

Summary of Economic Analyses of Alternative Configurations[1]

October and November, 1971

Scenario	Description	Nonrecurring Cost[2] (Billions 1970 $)	Allowable Non-recurring Cost[3] (Billions 1970 $)
400	MCDC RATO, 1979 FOC	7.3	10.4
401	Grumann TAHO, 1979 FOC	6.4	9.7
402	"TAOS", best case[4], 1979 FOC	6.4	10.3
403	"TAOS", middle case[5], 1979 FOC	6.8	10.0
404	"TAOS", worst case[6], 1979 FOC	7.3	9.2
405	Two-Stage Fully Reusable, Case C[7]		10.4
406	OSSA Reduced to 75 Percent (455 flights)		9.8
407	OSSA Reduced to 50 Percent (400 flights)	14.5	9.0
408	(407) with DoD Doubled (507 flights)		10.8
409	(407) with DoD Reduced to 75 Percent (367 flights)		8.6
410	DoD Adjusted for 624 Flight Model		12.7
411	Non-NASA Applications Adjusted for 624 Flight Model		12.7
412	(407) with Non-NASA Applications Increased 50 Percent (446 flights)		9.5
413	(407) with Non-NASA Applications Doubled (499 flights)		10.2
414	(407) with Non-NASA Applications Tripled (598 flights)		11.3

1. Based upon final Aerospace data, NASA and contractor data, and 514 Shuttle-Flight Mission Model.
2. Includes cost of Space Tug and Western Test Range.
3. Based upon a 10 percent discount rate.
4. Assumes Grumman Non-recurring costs and McDonnell Douglas costs per flight.
5. Assumes McDonnell Douglas costs.
6. Assumes McDonnell Douglas Non-recurring costs and Grumman costs per flight.
7. "Best" payload mix.

allowable non-recurring costs of from $18.6 billion, with the DoD activity doubled, to $10.8 billion with the OSSA and OMSF activity reduced by 50% and the DoD activity reduced by 25%. Since the non-recurring costs of the two-stage fully reusable configurations is given by Aerospace to be $14.5 billion, there is a requirement of somewhat more than 565 flights over the period 1979 - 1990 (Scenario 101) for the Shuttle to be cost effective.

Also given in Table 8.1 are the nominal values for the Aerospace Case C-1 (with baseline payloads adapted for reuse only) and the nominal values for Case C-2 ("best" mix of payloads and a 1985 Tug IOC). It is seen that under this latter case with 618 flights the Shuttle is not cost effective at 10%.

Table 8.2 contains a summary of cost-effectiveness analyses of alternative configurations and alternative costing of the two-stage fully reusable Shuttle by NASA and the Aerospace contractors. The alternative configurations appearing in this table include the RSIC of Grumman, the RATO, IVC, and HO/1 configurations of McDonnell Douglas, and the "Mini-Tech" and phased development approach to the two-stage configuration examined by NASA. It is seen that the non-recurring cost estimates which include the Western Test Range and the reusable Space Tug range from $6.4 billion (the Grumman TAHO) to $12.3 billion (the MCDAC HO/1). Given these non-recurring cost estimates and the allowable non-recurring costs based upon the cost-effectiveness analyses by MATHEMATICA, all of these combinations except the two-stage phased development approach with a 1985 IOC are cost-effective.

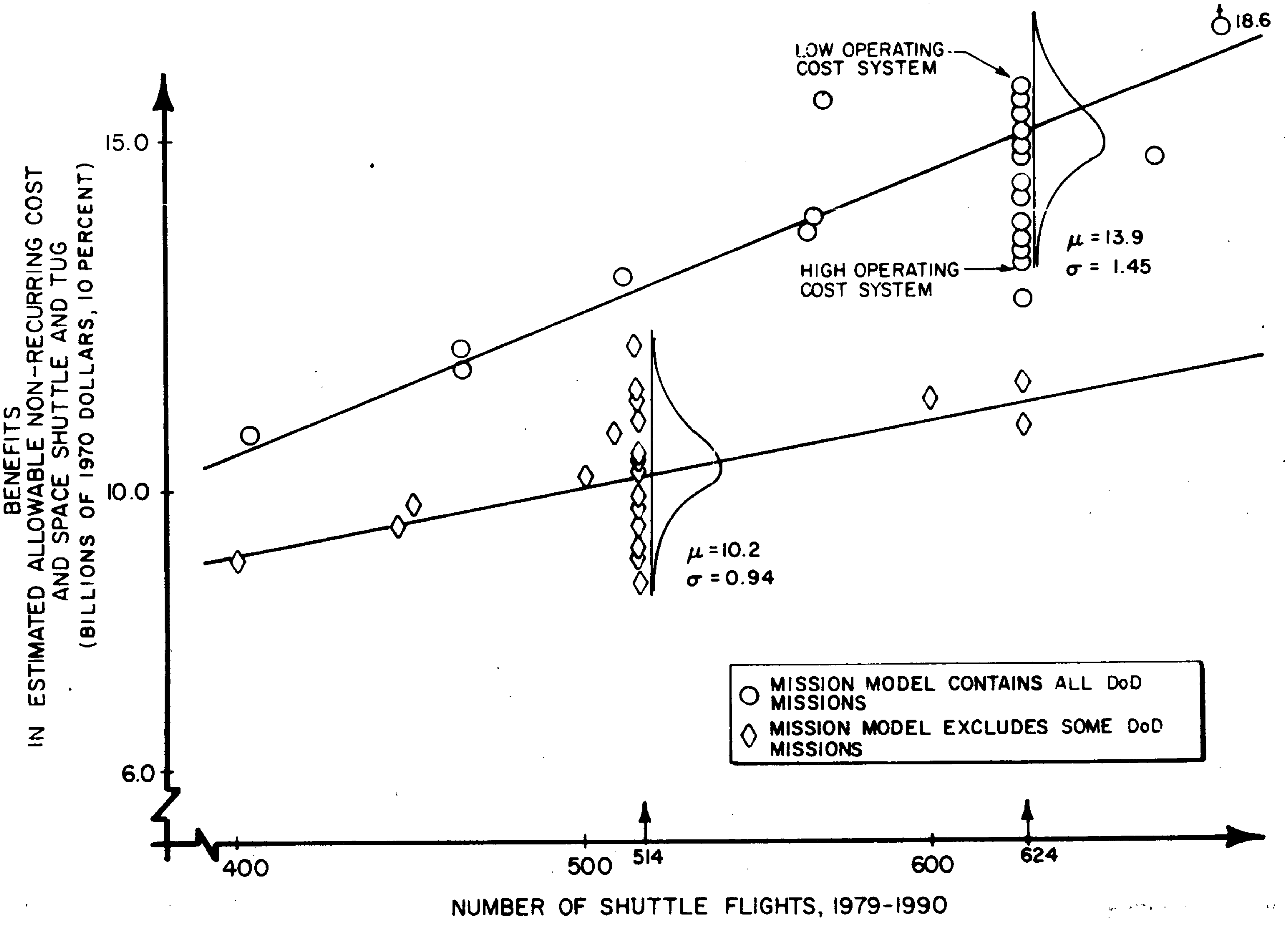
Table 8.3 contains a summary of the cost-effectiveness analyses performed on the alternative configurations during September, 1971, and Table 8.4 summarizes the analyses of the configurations performed over October and November, 1971. All of these analyses are based upon a 514 shuttle flight mission model representing a removal altogether of some DoD missions that were included in the data of Tables 8.1 and 8.2. Due to a lack of adequate definition for these missions, it was decided by the Aerospace Corporation not to include payload cost estimates for them in its final report. Launch costs for the missions, however, were given. It was decided by MATHEMATICA that since these missions were undefined and probably would remain so throughout the course of the analyses, they should be removed from the analysis altogether. They could be, however, reintroduced via a Scenario; and this has been done in Scenario 410 in Table 8.4. For this reason, the baseline case now appears as 514 shuttle flights as shown in Tables 8.3 and 8.4.

MATHEMATICA has attempted to make the new cost data as consistent with the two-stage fully reusable shuttle data as possible. Consequently, cost estimates for the Space Tug and Western Test Range as provided by the Aerospace Corporation were added to contractor and NASA data and phased in the appropriate manner.

Figures 8.1 to 8.3 show graphically the results of the cost-effectiveness analyses. Figure 8.1 displays the allowable non-recurring costs derived from the recurring cost savings associated with the alternative configurations for the 624 shuttle flight mission model, the 514 shuttle flight mission model and associated scenarios. Included in the estimates of recurring cost savings are all savings that pertain to launch vehicle direct costs and payload RDT&E, unit investment and operations cost savings due to payload reuse and shuttle related mass and volume effects. The vertical axis in Figure 8.1 is allowable non-recurring costs in billions of 1970 dollars evaluated at the 10% discount rate. The horizontal axis represents the number of shuttle flights in the mission model over the 1979 to 1990 period. Supporting data for the figure are found in Tables 8.1 through 8.4.

The statistical mean and the standard deviation for the allowable non-recurring for the 514 and 624 shuttle flight mission model data bases have been estimated and are given in Figure 8.1. For example, the data for the 624 flight mission model are given in Tables 8.1 and 8.2. Table 8.1 contains the summary of economic analyses for the two-stage fully reusable Shuttle along with alternative scenarios, and are plotted as circles for each estimate of allowable non-recurring in Figure 8.1. The estimates for the 514 flight mission model are presented in Tables 8.3 and 8.4 and are represented by the diamonds in Figure 8.1. Each of these estimates represent an independent computation of allowable non-recurring costs based upon the

Figure 8.1: Expected Benefits of a Space Shuttle and Tug System



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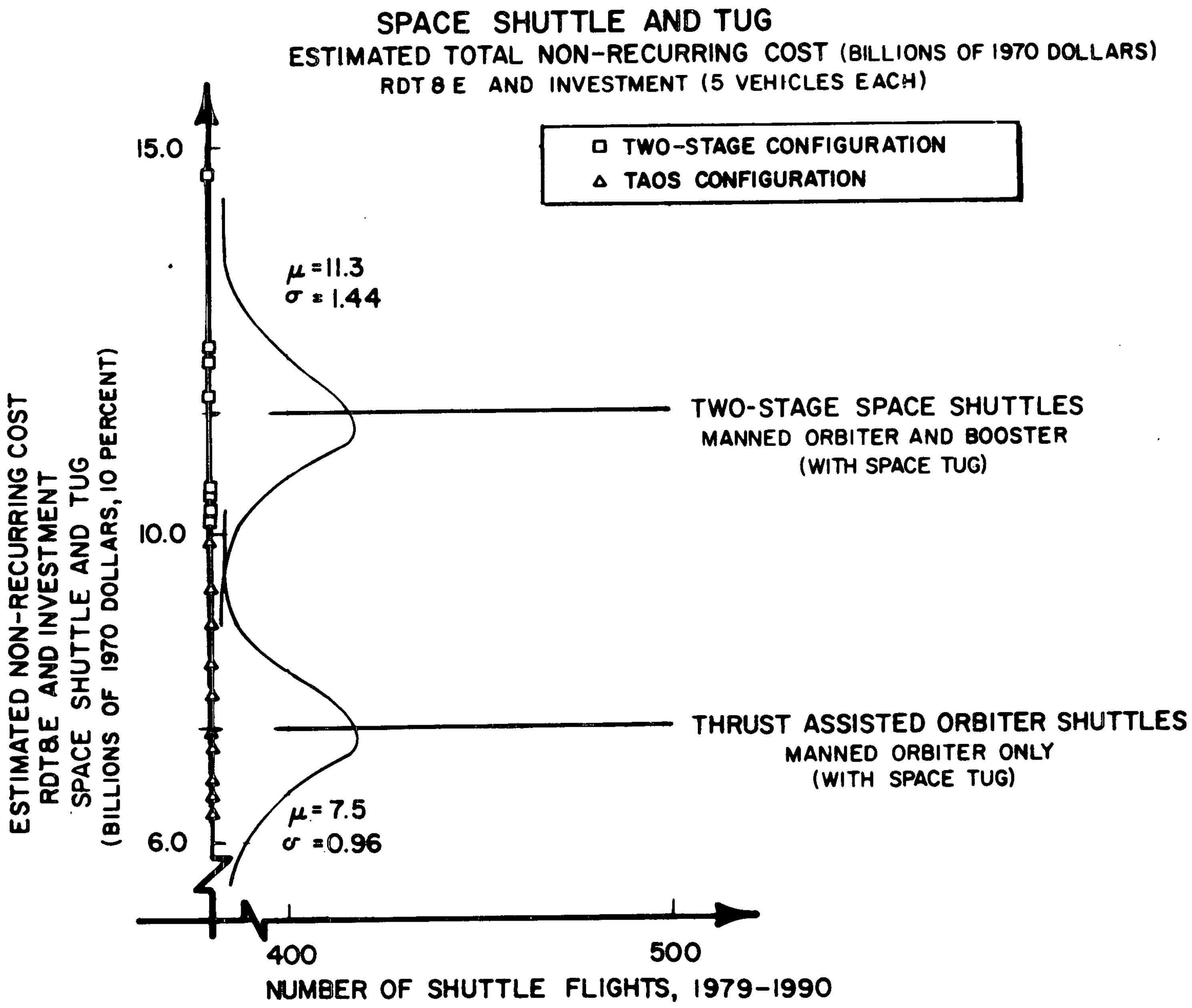


Figure 8.2: Estimated Non-Recurring Costs of Two-Stage and TAOS Space Shuttle and Tug Systems

incremental costs, non-recurring cost phasing and payload costs associated with each configuration. The means represent the average or expected values of allowable non-recurring costs for the 514 and 624 shuttle-flight data base. That is, we expect an allowable non-recurring of $10.2 billion for the reduced data base at 514 shuttle flights and $13.9 billion for the full data base at 624 shuttle flights. Applying the three sigma limits to these expected values (which includes 99 percent of the probability distribution), we find the allowable non-recurring cost for the reduced data base to range from $7.4 to $13.0 billion at 514 flights and a range of from $9.6 to $18.2 billion at 624 flights for the full data base.

As explained above, the difference between the 514 and 624 shuttle flight mission model data bases is due to the inclusion or exclusion of some DoD missions. The omitted missions as originally costed by Aerospace provided large economic benefits to the Space Shuttle System due to reuse, larger on the average than for the other payloads in the data base. This is why with the removal of these payloads in the 514 Shuttle flight mission model data base there is a smaller slope and reduced benefits over the range of shuttle flights.

Figure 8.2 gives the non-recurring costs -- RDT&E, Investment, Tug and Western Test Range -- for each configuration. The non-recurring cost estimates are plotted on the vertical axis with the two-stage configuration shown as diamonds and the alternative "TAOS" configurations shown as triangles. As in the case of the recurring costs given in the last figure, 8.1, the means and standard deviations for each of the classes of shuttles (fully reusable or TAOS) have been estimated and are shown. For the two-stage shuttle variety, the mean non-recurring cost is $11.3 billion with a one standard deviation being approximately $1.4 billion. For the TAOS configurations the mean non-recurring cost is $7.5 billion with a standard deviation of just under $1 billion.

Figure 8.3 combines Figures 8.1 and 8.2 showing the resulting allowable non-recurring cost and estimated actual non-recurring costs together. Shown on this figure are bands of uncertainty representing plus and minus one standard deviation for the allowable non-recurring and

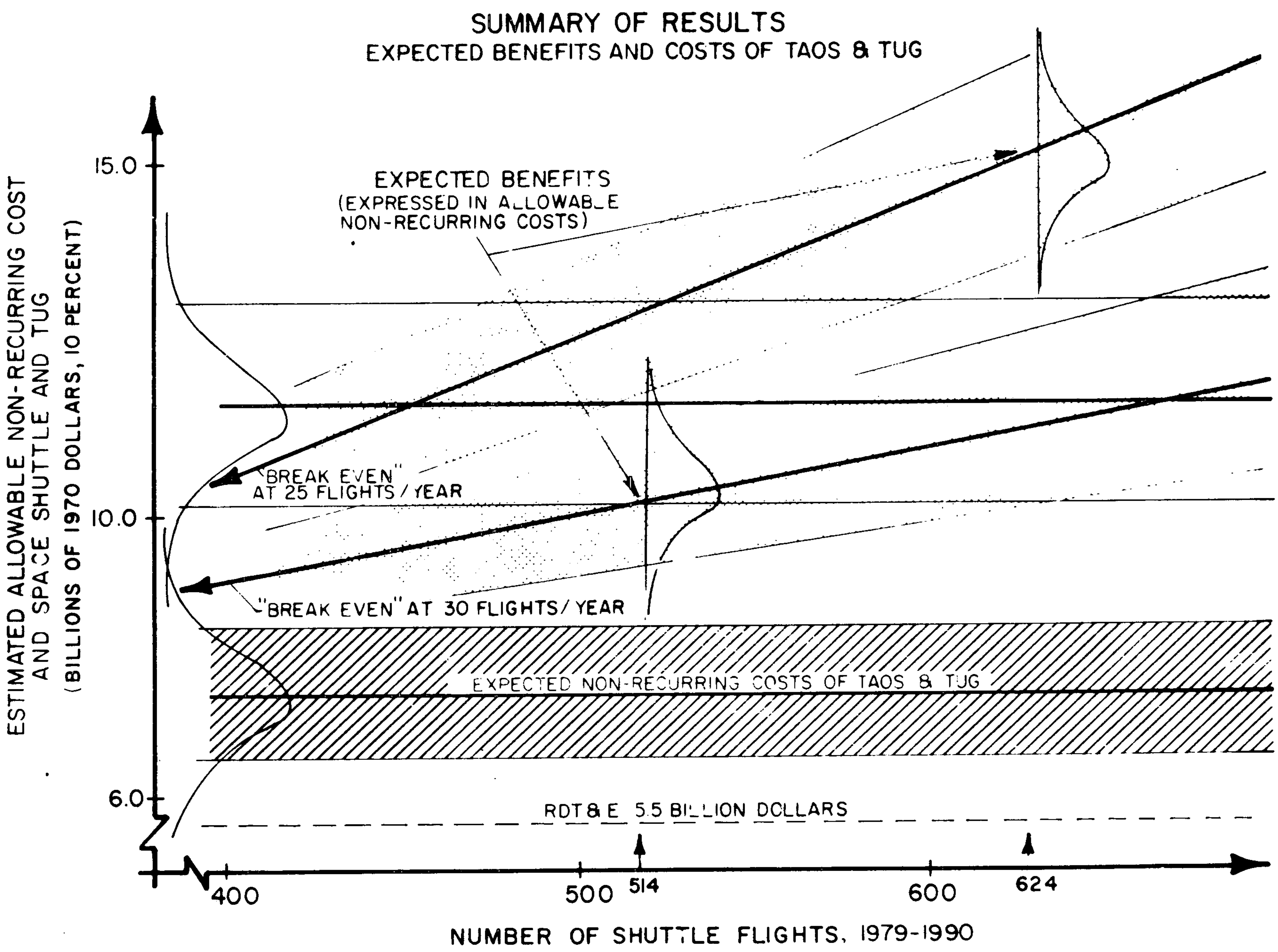


Figure 8.3 Estimated Costs and Benefits of Two-Stage and TAOS Space Shuttle and Tug Systems

estimated non-recurring costs.

It is seen that at the range of plus and minus one standard deviation, which covers about 70% of the probability distribution, the most pessimistic non-recurring cost for the TAOS configuration and the most pessimistic estimate for allowable non-recurring costs intersect at about 425 flights over the 1978 to 1990 time period or at 35 shuttle flights per year. Comparable results for the two-stage configuration is about 590 flights over the same time period, 49 shuttle flights per year.

8.3 Parametric Analysis of Payload Effects and Shuttle Incremental Costs

From the data bases provided by the Aerospace Corporation and LMSC and the economic models that MATHEMATICA developed for benefit/cost analyses of New Space Transportation Systems, the parameters of an equation have been estimated that express the effects of variations in payload effects and shuttle incremental costs on the present value of recurring cost savings of alternative shuttle configurations. With these results, it is possible to construct the Economic Trade-off Function of recurring versus non-recurring costs, the theoretical foundations of which were presented in Chapter 3.

The parameters of the equation were estimated using the computer program CAPTURE presented in our May, 1971 report.[2] With this program, the user can introduce into the economic analysis variations in shuttle incremental costs (the user cost per flight) and estimates of the payload effects, e.g., cost reductions in RDT&E, unit investment and operations costs due to relaxed payload mass and volume constraints (mass and volume effects), payload refurbishment, and on-orbit maintenance costs. The sensitivity of each candidate shuttle configuration to variations in the values of the parameters can then be observed.

Figure 8.4 outlines the structure of program CAPTURE.

As shown in Figure 8.4, baseline payload costs, i.e., costs of payloads embodying current technology, and the direct (incremental) costs of each launch vehicle in the New Expendable family is supplied to the program -- steps 1 and 2. The set of payloads for the NASA-DoD mission model is then broken down into four categories:

(a) Baseline expendable
(b) Baseline reusable
(c) Low cost expendable, and
(d) Low cost reusable

Step 3. To those payloads identified as "low cost payloads", factors for RDT&E, first unit cost, and operating cost are entered -- step 4. These "factors" are the ratios of the low cost payload RDT&E, unit cost, and operations cost to their baseline payload counterparts. In this model, one set of factors is applied to the entire class of low cost payloads, and this is, therefore, a generalization of a set of low cost factors across the entire mission model. Also factors for refurbishment, update, and on-orbit maintenance are entered. For refurbishment, this is a value for the ratio of refurbishment costs to new unit cost, and is applied to those payloads that have been identified (in step 2) as refurbishable payloads. For on-orbit maintenance, the factor is the expected ratio of these costs to new unit cost.

In step 5 values are entered for incremental Space Shuttle and Tug costs. In steps 6 and 7 the satellite and launch vehicle traffic models (supplied by Aerospace Corporation) are joined with the payload and launch vehicle cost elements; and in step 8 the present value of costs for each program in the mission model is computed for:

(a) The Expendable mode, and
(b) The Space Shuttle mode.

The program then selects the lowest cost mode -- step 9 -- for each program in the mission model. The costs of a shuttle only system also stored. Given the present values of the sustaining costs of each system -- step 10 -- and the present value of the non-recurring costs of the New Expendable system -- step 11 -- the present value of allowable non-recurring costs of the Space Shuttle and Tug system under the conditions of either a Shuttle only or mixed fleet are computed -- step 12. Finally, with the pertinent redistribution factor the present values are converted to undiscounted values -- steps 13 and 14.

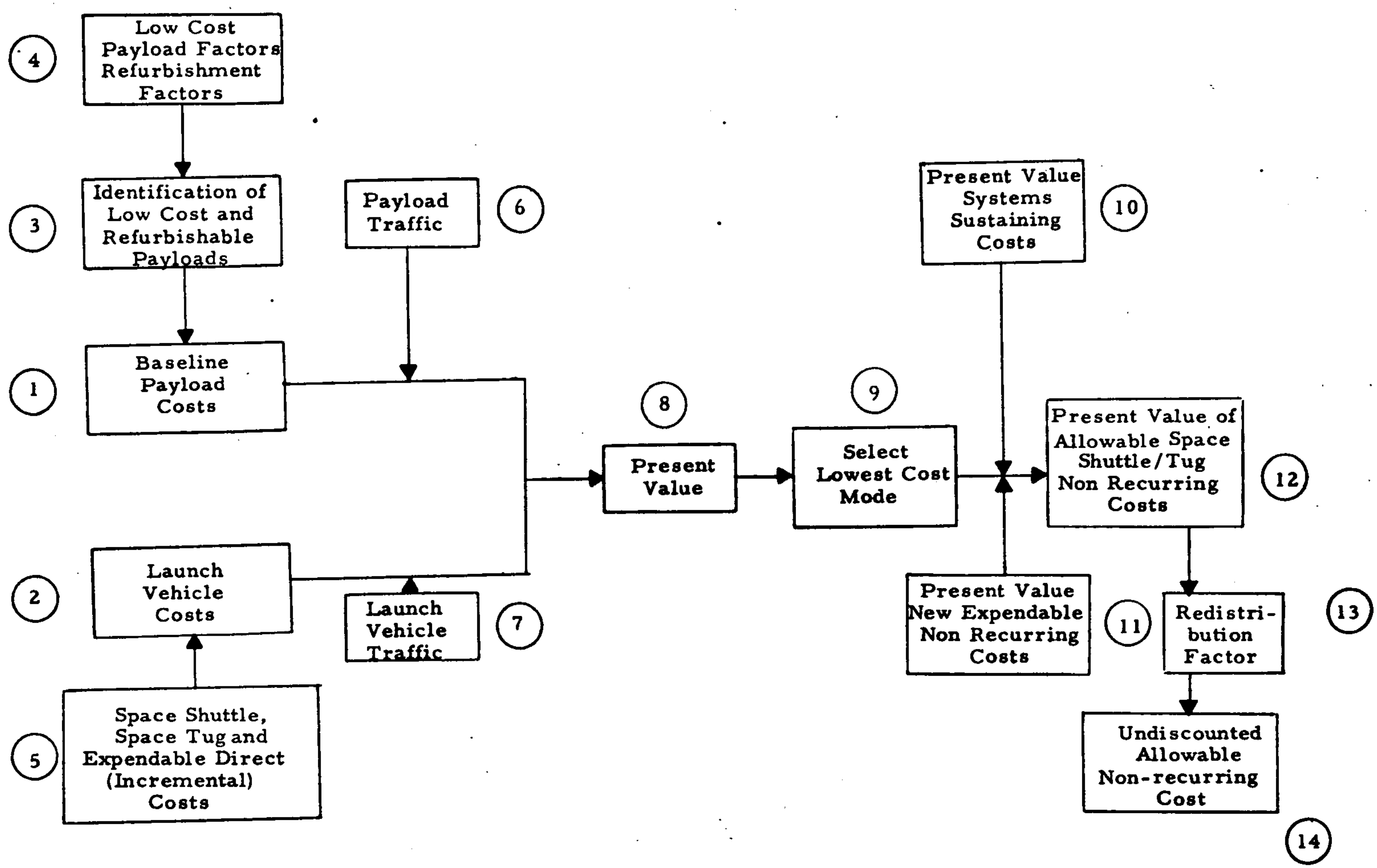


Figure 8.4 - PAYLOAD EFFECTS AND PROGRAM CAPTURE FOR SPACE SHUTTLE COST ANALYSIS

The variables involved in the analysis follow:

PVANR	=	Present value at 10 percent discount rate of allowable non-recurring cost in millions of 1970 dollars;
ACTIV	=	Activity level in terms of number of shuttle flights;
ICOST	=	The incremental cost (user's fee) of the Shuttle.
EXRDT	=	The ratio of expendable system satellite RDT&E to the baseline, current expendable, RDT&E.
EXINV	=	The ratio of expendable system satellite unit investment to the baseline, current expendable, satellite unit investment.
SHRDT	=	The ratio of shuttle satellite RDT&E to the baseline, current expendable, RDT&E.
SHINV	=	The ratio of shuttle satellite unit investment to the baseline, current expendable, unit investment.
REFRB	=	The ratio of shuttle satellite refurbishment to shuttle satellite unit cost.
ONORB	=	The ratio of shuttle satellite on-orbit maintenance to shuttle satellite unit cost.

Varying inputs to the computer model CAPTURE were applied covering a range of estimates for the payload effects that includes the specific satellites studied by LMSC and the results of the Aerospace Corporation. A summary of the Aerospace and LMSC inputs appears in Table 8.5. The other inputs for the estimation were devised by MATHEMATICA.

The following equation expresses the present value of allowable non-recurring costs in millions of 1970 dollars at the 10 percent discount rate of a shuttle evaluated against the New Expendable system and contains the full DoD mission model in the data base:

$$
\begin{aligned}
(8.1)\qquad \text{PVANR} = \text{ACTIV}\ [&-.384\ (\text{ICOST}) + 7.049\ (\text{EXRDT}) \\
&+ 11.371\ (\text{EXINV}) - 2.250 \\
&- 8.173\ (\text{SHINV}) - 5.040\ (\text{REFRB}) \\
&- 2.205\ (\text{ONORB}) + 6.090].
\end{aligned}
$$

Table 8.5 - Summary of Estimates of Payload Effects and Refurbishment Cost[1]

Example	γ_1		γ_2		γ_3		δ	ω
	NE[2]	S/T[3]	NE	S/T	NE	S/T	S/T	S/T
LMSC - OAO	0.54	0.50	0.58	0.48	0.60	0.48	0.57[5]	0.10
							0.34[6]	0.10
LMSC - SEO	0.84	0.73	0.79	0.70	0.98	0.54	0.67[5]	0.10
							0.45[6]	0.10
							0.30	0.10
LMSC - SRS	0.86	0.61	0.83	0.68	1.0	0.98	0.40[7]	0.10[7]
Average Aerospace Corporation I[8]	0.87	0.65	0.90	0.78	1.0	0.62	0.30	0.10
Average Aerospace Corporation II[9]	0.96	.85	.97	.83[10]	.91	0.66[10]	.39	.10
No Mass-Cost Effects	1.0	1.0	1.0	1.0	1.0	1.0	0.30	0.10

1. Space Shuttle and Tug costs are assumed to be $4.57 million and $0.46 million.
2. New Expendable System Low Cost Expendable Payloads.
3. Space Suttle and Tug Low Cost Payloads.
4. Assumes distribution of Non-Recurring Costs identical to that shown by the Aerospace Corporation.
5. Without module refurbishment.
6. With module refurbishment.
7. This value was assumed by MATHEMATICA.
8. Interim Report, May, 1971.
9. Final Report, August, 1971.
10. Approximated by MATHEMATICA.

Removal of the so-called "poorly specified" DoD missions from the data base yields:

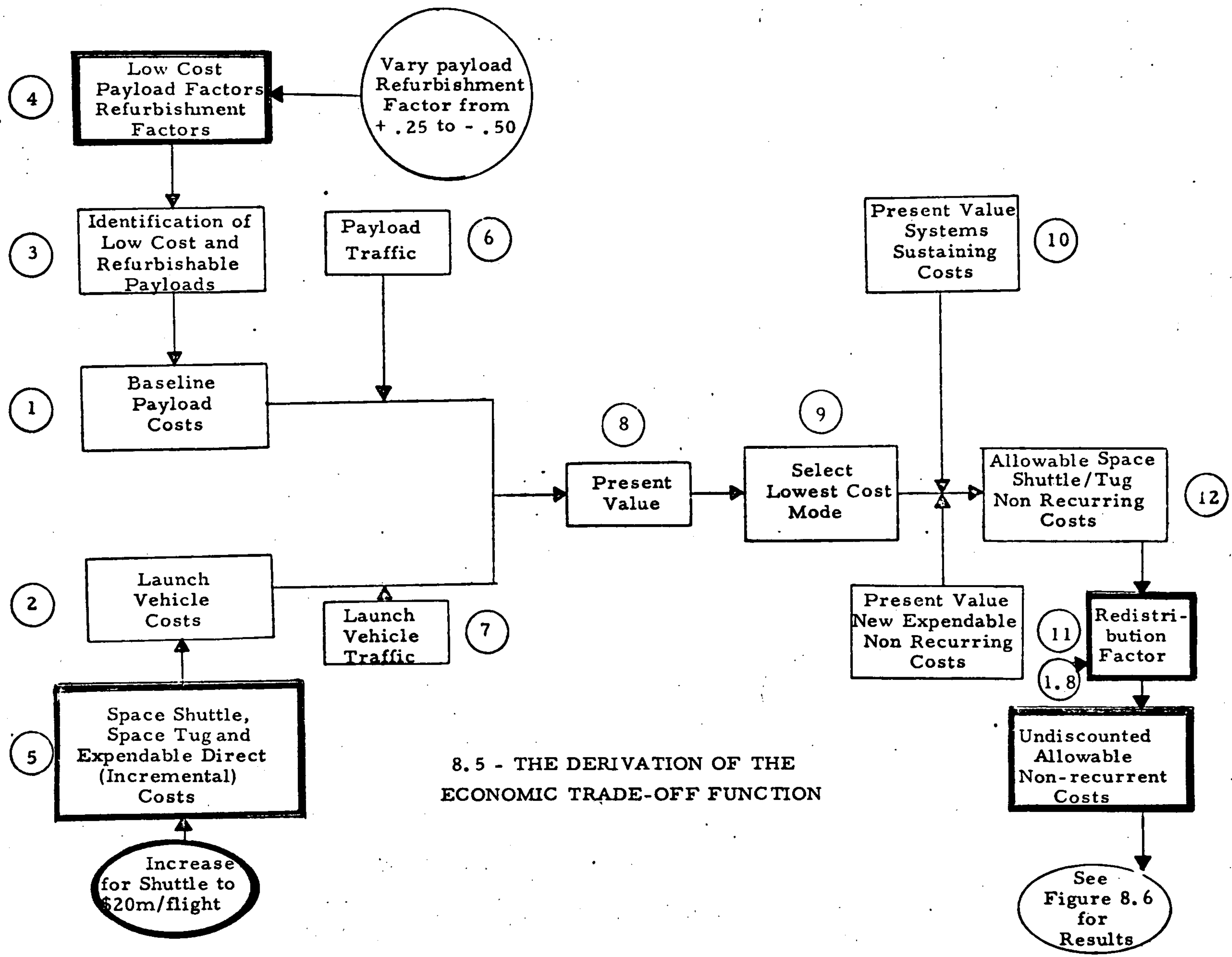
(8.2) $$\text{PVANR} = \text{ACTIV} [-.384\,(\text{ICOST}) + 5.188\,(\text{EXRDT}) + 8.369\,(\text{EXINV}) - 1.548\,(\text{SHRDT}) - 6.015\,(\text{SHINV}) - 3.709\,(\text{REFRB}) - 1.623\,(\text{ONORB}) + 4.482$$

Present values of allowable non-recurring (ANR) costs may then be redistributed into undiscounted dollars by a factor that is dependent upon the funding pattern and IOC date of the configuration. For a 1979 IOC, the factor varies between 1.7 and 1.9. The configurations with a rapid build-up in required non-recurring costs, e.g., the two-stage fully reusable, have a redistribution factor of 1.7; the RATO, TAHO, and TAOS configurations with a somewhat slower build-up have a factor of 1.8.

Figure 8.5 illustrates how the equations as estimated from the computer program CAPTURE are used to determine the Economic Trade-off Function (ETF). As presented in Chapter 3, the ETF provides the boundary of allowable non-recurring costs for a graph of non-recurring vs. recurring costs of alternative Shuttle systems. The slope of the ETF is a function of activity level, payload effects, and the discount rate. In Figure 8.5 variations in the Space Shuttle incremental cost and payload refurbishment rates are indicated. The effect of these variations on allowable non-recurring costs provides the results that enable the derivation of the ETF as shown in Figure 8.6.

Figure 8.6 illustrates the effect of variations in the activity level, payload refurbishment factor, and data base on the trade-off lines. The slopes of the lines are determined by the loss in the present value of ANR -- given in equations (8.1) and (8.2) as \$.384 million for each additional \$1.0 million in undiscounted shuttle cost per flight -- and the scale of the mission model. Hence, for the 514 shuttle flight mission model data base with a redistribution factor of 1.8 an additional \$1 million in shuttle cost per flight is translated into approximately \$355 million in loss of ANR as shown by the slope of the trade-off line. For the 624 flight mission model data base, the equivalent loss in ANR is \$431 million.

The effect of variation in the payload refurbishment factor from .25 to .50 is shown by the shaded areas around the 514 and 624 flight mission model trade-off lines. The nominal refurbishment factor is .39,



8.5 - THE DERIVATION OF THE ECONOMIC TRADE-OFF FUNCTION

RECURRING COSTS (PER FLIGHT) vs NON-RECURRING COSTS OF ALTERNATE CONFIGURATIONS
DECEMBER 15, 1971 DATA

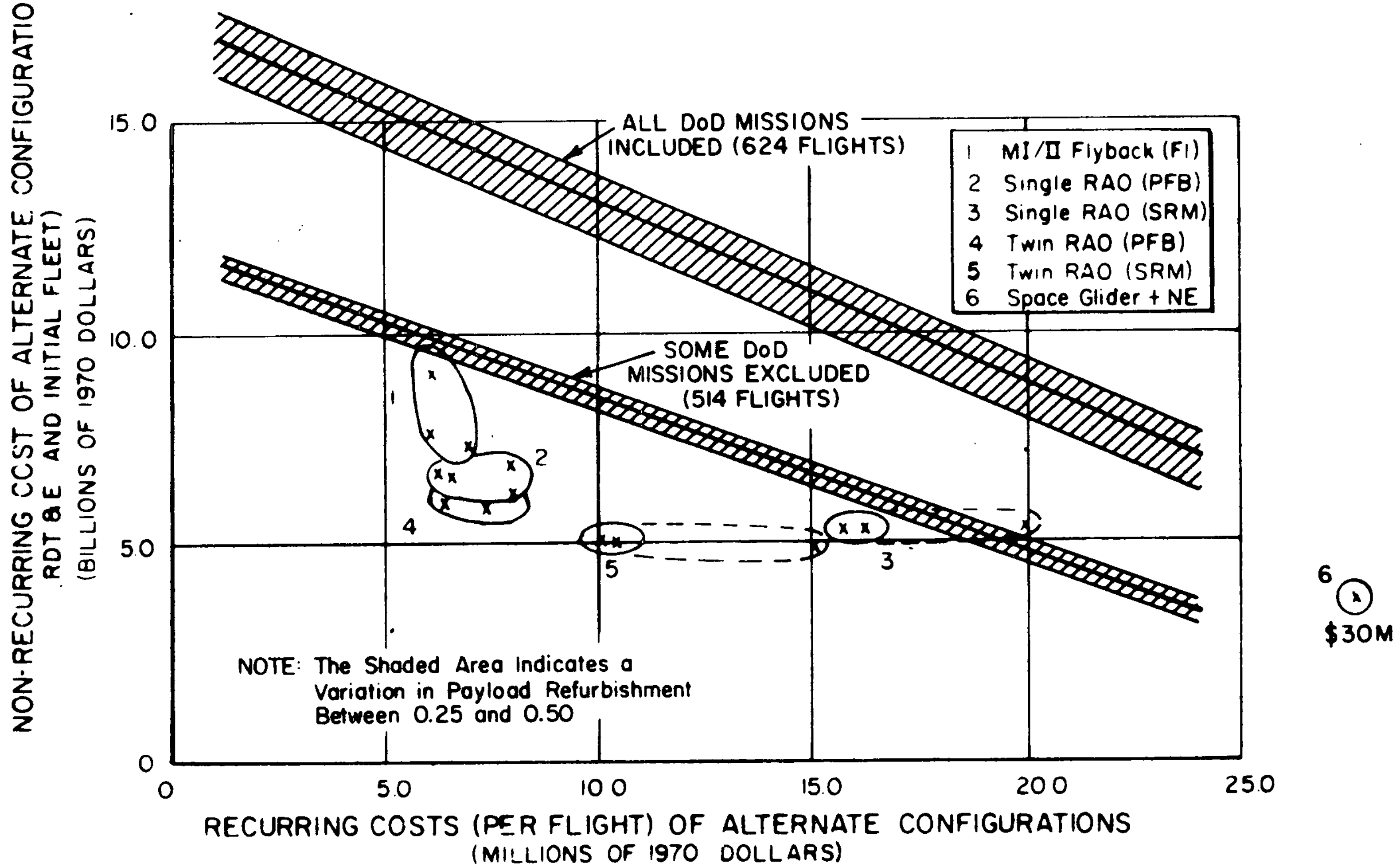


Figure 8.6 Construction of the Economic Trade-off Function Based Upon 10 Percent Discount Rate

the average factor for payload refurbishment provided by the Aerospace Corporation in its Final Report.

FOOTNOTES TO CHAPTER 8.0

1. The payload data is from the Aerospace Corporation's Appendix A to Volumes III and VI in which cost adjustment have been made for equal reliability between the expendable launch vehicles and payloads and Shuttle System and payloads. Reference: The Aerospace Corporation, Integrated Operations/Payloads/Fleet Analysis Final Report, Volumes III, IIIA, VI, and VIA, August, 1971.

2. See MATHEMATICA, Economic Analysis of New Space Transportation Systems, May, 1971, Chapter 2.0 pp. 2-109 ff.

Appendix 8A: Life-Cycle Cost Summary Data and Cost-Effectiveness Analyses

This appendix is organized in four sections, corresponding to the data in Tables 8.1 through 8.4. Presented are the Life-Cycle Cost Summary data and the Equal Capability analysis for each configuration.

On the Life-Cycle Cost Summary pages, it will be seen that all non-recurring costs for the non-Aerospace costed, two-stage configurations have been combined, appearing in the RDT&E column. Appearing in the Non-recurring Investment column is the $75 million in non-recurring costs required for expendables during the Shuttle's phase-in period. It was assumed that these costs would be associated with each configuration examined.

Preceding the tables in each section is a figure with the funding patterns of a typical shuttle configuration and the New Expendable System.

8A.1 Table 8.1 Data

The data contained within this section represent the Life-Cycle Cost Summaries and Cost-Effectiveness analyses for the two-stage fully reusable shuttle. The data base contains all of the DoD missions, and is predicated upon 624 shuttle flights over the 1979-1990 operating period.

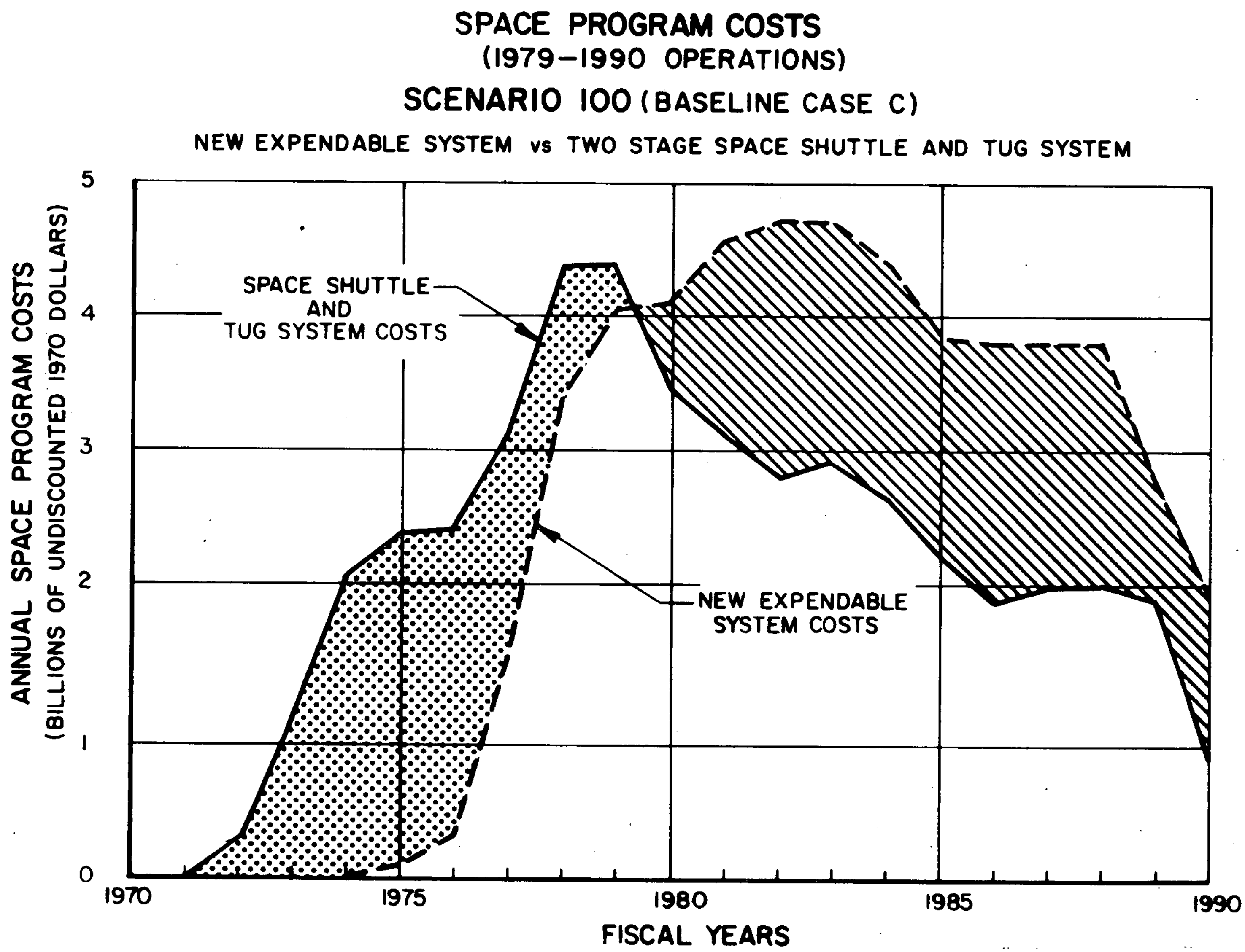


Figure 8A. 1 Space Program Costs: New Expendable System Versus Two-Stage Space Shuttle and Tug System

LIFE CYCLE COST SUMMARY DATA
SCENARIO 100 - BASELINE CASE C
SPACE SHUTTLE SYSTEM
(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	28	0	0	2382
1976	2307	25	98	0	0	2430
1977	1876	197	450	107	533	3163
1978	1033	555	992	270	1547	4397
1979	315	1018	1064	357	1648	4402
1980	0	829	1048	373	1210	3460
1981	0	410	1158	391	1158	3117
1982	0	15	1197	392	1219	2823
1983	0	0	1271	435	1215	2921
1984	0	0	881	390	1393	2664
1985	0	0	558	445	1226	2229
1986	0	0	422	411	1057	1890
1987	0	0	400	445	1150	1995
1988	0	0	362	424	1244	2030
1989	0	0	241	451	1205	1897
1990	0	0	66	410	525	1001
TOTAL	11434	3059	10236	5301	16330	46360

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 100 - BASELINE CASE C
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT RATE	1970 PRESENT VALUES CE	NE	SH	COST DIFFERENCES CE-NE	NE-SH	CE-SH
1	401884	381834	255729	20050	126104	146154
2	185637	176526	124565	9111	51961	61072
3	114645	109296	81193	5548	28103	33652
4	80229	76411	59686	3818	16725	20543
5	59971	57158	46878	2812	10280	13092
6	46817	44652	38392	2164	6259	8424
7	37673	35954	32359	1718	3595	5313
8	31002	29607	27849	1395	1757	3153
9	25956	24803	24348	1153	454	1607
10	22030	21064	21551	966	-486	479
11	18907	18088	19264	818	-1175	-356
12	16377	15676	17358	700	-1681	-980
13	14295	13691	15745	603	-2053	-1449
14	12561	12037	14362	524	-2325	-1801
15	11100	10643	13164	457	-2521	-2064
16	9858	9457	12117	401	-2660	-2259
17	8793	8440	11194	353	-2753	-2400
18	7874	7562	10374	312	-2812	-2499
19	7076	6799	9643	277	-2843	-2566
20	6379	6132	8986	246	-2853	-2606

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 101 - OSSA REDUCED BY 25 PERCENT

SPACE SHUTTLE SYSTEM

. (MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	21	0	0	2375
1976	2307	25	76	0	0	2406
1977	1876	197	378	99	506	3056
1978	1033	555	840	252	1462	4142
1979	315	1018	878	338	1553	4102
1980	0	829	850	361	1095	3135
1981	0	410	950	370	1054	2784
1982	0	15	1023	360	1133	2531
1983	0	0	1086	412	1143	2641
1984	0	0	733	383	1278	2394
1985	0	0	444	421	1142	2007
1986	0	0	333	383	1002	1718
1987	0	0	310	415	1069	1794
1988	0	0	281	394	1144	1819
1989	0	0	195	419	1115	1729
1990	0	0	55	380	486	921
TOTAL	11434	3059	8453	4967	15202	43115

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 101 - OSSA REDUCED BY 25 PERCENT

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT RATE	1970 PRESENT VALUES CE	NE	SH	COST DIFFERENCES CE-NE	NE-SH	CE-SH
1	367472	349602	230808	17869	118793	136663
2	169759	161650	113066	8108	48584	56692
3	105027	100096	74080	4930	26016	30946
4	73371	69983	54714	3387	15269	18656
5	54843	52351	43157	2491	9193	11685
6	42811	40896	35482	1914	5413	7326
7	34447	32929	30012	1517	2916	4434
8	28344	27114	25913	1230	1201	2431
9	23728	22713	22723	1015	-9	1005
10	20137	19288	20167	849	-879	-29
11	17281	16562	18072	718	-1510	-791
12	14966	14352	16322	614	-1970	-1356
13	13062	12533	14838	528	-2304	-1775
14	11476	11018	13563	458	-2545	-2087
15	10140	9741	12456	399	-2715	-2315
16	9004	8654	11485	349	-2830	-2481
17	8031	7723	10628	307	-2905	-2597
18	7191	6919	9866	271	-2947	-2675
19	6461	6221	9185	240	-2964	-2723
20	5824	5610	8572	213	-2961	-2748

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 102 - OSSA AND OMSF REDUCED BY 50 PERCENT

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	25	53	0	0	2385
1977	1876	197	300	92	479	2944
1978	1033	555	660	233	1377	3858
1979	315	1016	633	319	1437	3722
1980	0	829	597	321	964	2711
1981	0	410	676	331	864	2281
1982	0	15	805	314	912	2046
1983	0	0	888	370	952	2210
1984	0	0	585	320	1079	1984
1985	0	0	323	372	922	1617
1986	0	0	220	330	809	1359
1987	0	0	201	363	837	1401
1988	0	0	181	344	894	1419
1989	0	0	121	370	867	1358
1990	0	0	33	327	368	728
TOTAL	11434	3059	6290	4406	12761	37950

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 102 - OSSA AND OMSF REDUCED BY 50 PERCENT

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	302945	287247	191269	15698	95978	111676
2	140166	133104	94868	7062	38235	45298
3	86855	82597	62867	4257	19730	23988
4	60772	57872	46913	2900	10958	13859
5	45497	43381	37351	2115	6029	8145
6	35570	33957	30969	1612	2988	4601
7	28664	27396	26396	1268	1000	2268
8	23621	22601	22949	1020	-348	671
9	19803	18967	20252	835	-1284	-449
10	16829	16135	18079	693	-1943	-1249
11	14461	13878	16287	582	-2408	-1825
12	12541	12046	14781	494	-2735	-2240
13	10959	10536	13498	422	-2961	-2538
14	9640	9276	12390	363	-3113	-2749
15	8528	8213	11422	314	-3209	-2894
16	7581	7307	10571	274	-3263	-2989
17	6769	6530	9815	239	-3285	-3045
18	6068	5858	9140	210	-3282	-3072
19	5458	5273	8534	184	-3261	-3076
20	4925	4761	7987	163	-3225	-3062

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 103 - 102 WITH DOD INCREASED BY 50 PERCENT

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	25	57	0	0	2389
1977	1876	197	362	118	667	3220
1978	1033	555	795	307	1911	4601
1979	315	1018	715	385	1976	4409
1980	0	829	646	368	1256	3099
1981	0	410	754	373	1107	2644
1982	0	15	996	361	1176	2548
1983	0	0	1121	428	1249	2798
1984	0	0	700	372	1406	2478
1985	0	0	343	427	1183	1953
1986	0	0	220	378	1056	1654
1987	0	0	201	419	1053	1673
1988	0	0	181	391	1109	1681
1989	0	0	121	416	1088	1625
1990	0	0	33	375	462	870
TOTAL	11434	3059	7259	5118	16699	43569

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 103 - 102 WITH DOD INCREASED BY 50 PERCENT

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	382441	364278	233565	18163	130713	148876
2	176802	168619	114451	8183	54168	62351
3	109472	104529	75028	4942	29501	34443
4	76541	73167	55452	3374	17714	21089
5	57263	54796	43773	2467	11023	13490
6	44740	42855	36016	1885	6838	8724
7	36032	34545	30487	1486	4057	5544
8	29675	28475	26343	1199	2132	3332
9	24865	23879	23116	985	762	1748
10	21120	20298	20529	821	-230	590
11	18139	17447	18407	692	-960	-268
12	15722	15133	16634	589	-1500	-911
13	13733	13227	15128	505	-1900	-1394
14	12075	11638	13834	436	-2195	-1758
15	10677	10297	12709	379	-2411	-2031
16	9488	9156	11722	331	-2565	-2234
17	8468	8177	10850	290	-2672	-2381
18	7588	7331	10074	256	-2742	-2486
19	6822	6596	9379	226	-2783	-2557
20	6153	5952	8755	200	-2802	-2601

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA
SCENARIO 104 - 102 WITH DOD DOUBLED
SPACE SHUTTLE SYSTEM
(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	25	61	0	0	2393
1977	1876	197	424	145	856	3498
1978	1033	555	929	380	2444	5341
1979	315	1018	796	451	2515	5095
1980	0	829	695	416	1547	3487
1981	0	410	832	415	1350	3007
1982	0	15	1188	408	1439	3050
1983	0	0	1354	486	1546	3386
1984	0	0	815	423	1733	2971
1985	0	0	363	482	1444	2289
1986	0	0	220	426	1302	1948
1987	0	0	201	475	1269	1945
1988	0	0	181	439	1325	1945
1989	0	0	121	463	1308	1892
1990	0	0	33	423	557	1013
TOTAL	11434	3059	8227	5832	20635	49187

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 104 - 102 WITH DOD DOUBLED

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	461937	441308	275860	20629	165448	186077
2	213438	204134	134034	9304	70100	79404
3	132089	126462	87190	5627	39272	44899
4	92311	88463	63991	3847	24471	28319
5	69029	66210	50194	2818	16016	18835
6	53910	51752	41063	2158	10688	12847
7	43399	41694	34579	1705	7114	8820
8	35729	34350	29736	1379	4614	5993
9	29926	28790	25980	1136	2810	3946
10	25411	24462	22980	949	1481	2430
11	21817	21015	20528	802	486	1288
12	18904	18220	18486	684	-266	418
13	16507	15918	16758	588	-839	-250
14	14509	13999	15278	509	-1278	-768
15	12826	12382	13995	444	-1613	-1168
16	11395	11005	12873	389	-1868	-1478
17	10167	9825	11885	342	-2060	-1717
18	9107	8805	11008	302	-2203	-1900
19	8186	7918	10225	268	-2306	-2038
20	7382	7143	9522	238	-2378	-2140

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 105 - 102 WITH DOD REDUCED BY 25 PERCENT

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

	NON-RECURRING COSTS			RECURRING COSTS		TOTAL
FISCAL YEAR	LAUNCH RDT&E	VEHICLE INVEST.	PAYLOAD RDT&E	LAUNCH	PAYLOAD	
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	25	51	0	0	2383
1977	1876	197	269	78	384	2804
1978	1033	555	593	196	1110	3487
1979	315	1016	592	286	1168	3379
1980	0	829	573	297	818	2517
1981	0	410	637	310	743	2100
1982	0	15	709	290	780	1794
1983	0	0	771	341	804	1916
1984	0	0	527	295	916	1738
1985	0	0	313	344	791	1448
1986	0	0	220	306	686	1212
1987	0	0	201	335	729	1265
1988	0	0	181	320	786	1287
1989	0	0	121	347	757	1225
1990	0	0	33	303	320	656
TOTAL	11434	3059	5805	4048	10792	35138

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 105 - 102 WITH DOD REDUCED BY 25 PERCENT
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	263198	248732	170121	14465	78611	93076
2	121848	115346	85077	6501	30269	36771
3	75546	71631	56786	3915	14845	18760
4	52888	50224	42644	2663	7580	10243
5	39614	37674	34140	1940	3533	5473
6	30985	29509	28445	1476	1063	2539
7	24980	23822	24350	1158	-528	630
8	20594	19664	21253	930	-1589	-658
9	17272	16511	18820	760	-2308	-1548
10	14684	14054	16853	630	-2799	-2169
11	12622	12094	15226	528	-3132	-2603
12	10950	10503	13855	446	-3352	-2905
13	9572	9191	12683	381	-3492	-3110
14	8423	8095	11668	327	-3572	-3245
15	7453	7171	10779	282	-3608	-3325
16	6628	6383	9995	245	-3612	-3366
17	5920	5706	9298	213	-3591	-3377
18	5308	5121	8673	186	-3552	-3365
19	4776	4612	8112	164	-3499	-3335
20	4310	4166	7603	144	-3437	-3292

NOTES -- CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 106 - 102 WITH NON-NASA APPLICATIONS INCREASED BY 50 **PERCENT**

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

	NON-RECURRING COSTS			RECURRING COSTS		TOTAL
FISCAL YEAR	LAUNCH VEHICLE RDT&E	LAUNCH VEHICLE INVEST.	PAYLOAD RDT&E	LAUNCH	PAYLOAD	
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	25	53	0	0	2385
1977	1876	197	313	103	502	2991
1978	1033	555	690	258	1447	3983
1979	315	1018	653	332	1511	3829
1980	0	829	621	347	1032	2829
1981	0	410	694	364	906	2374
1982	0	15	819	324	951	2109
1983	0	0	907	404	1000	2311
1984	0	0	614	333	1135	2082
1985	0	0	346	405	969	1720
1986	0	0	228	345	843	1416
1987	0	0	202	386	882	1470
1988	0	0	181	367	950	1498
1989	0	0	121	407	911	1439
1990	0	0	33	340	378	751
TOTAL	11434	3059	6489	4715	13417	39114

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 106 - 102 WITH NON-NASA APPLICATIONS INCREASED BY 50 PERCENT
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT RATE	1970 PRESENT VALUES CE	NE	SH	COST DIFFERENCES CE-NE	NE-SH	CE-SH
1	318382	299758	200016	18623	99741	118365
2	147288	138887	98914	8400	39973	48374
3	91256	86178	65374	5078	20803	25882
4	63844	60375	48669	3469	11705	15175
5	47791	45253	38667	2537	6586	9124
6	37360	35420	32000	1940	3420	5360
7	30103	28573	27228	1530	1345	2875
8	24805	23570	23637	1234	-66	1168
9	20793	19779	20829	1014	-1050	-36
10	17669	16824	18571	845	-1746	-901
11	15182	14470	16711	712	-2240	-1528
12	13165	12558	15150	606	-2591	-1985
13	11504	10984	13821	520	-2837	-2317
14	10116	9669	12675	449	-3005	-2556
15	8950	8560	11675	390	-3115	-2724
16	7957	7616	10796	340	-3160	-2839
17	7104	6805	10017	299	-3212	-2913
18	6367	6104	9322	263	-3217	-2954
19	5727	5494	8698	232	-3203	-2971
20	5167	4961	8135	206	-3174	-2968

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 107 - 102 WITH NON-NASA APPLICATIONS DOUBLED

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

	NON-RECURRING COSTS			RECURRING COSTS		TOTAL
FISCAL YEAR	LAUNCH RDT&E	VEHICLE INVEST.	PAYLOAD RDT&E	LAUNCH	PAYLOAD	
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	25	53	0	0	2385
1977	1876	197	326	115	526	3040
1978	1033	555	719	282	1517	4106
1979	315	1018	672	346	1585	3936
1980	0	829	645	373	1099	2946
1981	0	410	713	397	948	2468
1982	0	15	834	334	990	2173
1983	0	0	926	438	1047	2411
1984	0	0	643	346	1190	2179
1985	0	0	370	439	1017	1826
1986	0	0	237	361	877	1475
1987	0	0	203	410	928	1541
1988	0	0	181	391	1006	1578
1989	0	0	121	444	955	1520
1990	0	0	33	353	389	775
TOTAL	11434	3059	6690	5029	14074	40286

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 107 - 102 WITH NON-NASA APPLICATIONS DOUBLED

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	333818	312268	208763	21549	103505	125054
2	154410	144671	102959	9739	41711	51450
3	95658	89758	67881	5899	21876	27776
4	66916	62878	50424	4038	12453	16491
5	50085	47125	39983	2960	7142	10102
6	39150	36882	33030	2267	3851	6119
7	31542	29750	28060	1792	1690	3482
8	25988	24539	24324	1449	215	1664
9	21784	20590	21407	1193	-816	376
10	18510	17513	19063	996	-1549	-552
11	15903	15061	17135	841	-2073	-1231
12	13789	13071	15519	717	-2448	-1730
13	12048	11431	14144	617	-2713	-2096
14	10597	10062	12960	534	-2897	-2363
15	9373	8907	11928	465	-3020	-2555
16	8332	7924	11022	407	-3097	-2690
17	7439	7080	10219	358	-3139	-2780
18	6667	6350	9503	316	-3153	-2836
19	5996	5715	8862	280	-3146	-2865
20	5410	5160	8284	249	-3123	-2873

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 108 - 102 WITH NON-NASA APPLICATIONS TRIPLED

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH RDT&E	NON-RECURRING COSTS VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	25	53	0	0	2385
1977	1876	197	352	138	573	3136
1978	1033	555	778	331	1657	4354
1979	315	1018	711	373	1733	4150
1980	0	829	693	425	1234	3181
1981	0	410	750	463	1032	2655
1982	0	15	863	354	1068	2300
1983	0	0	964	506	1142	2612
1984	0	0	701	372	1301	2374
1985	0	0	417	506	1112	2035
1986	0	0	254	392	945	1591
1987	0	0	205	457	1019	1681
1988	0	0	181	438	1118	1737
1989	0	0	121	518	1043	1682
1990	0	0	33	379	410	822
TOTAL	11434	3059	7090	5652	15387	42622

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 108 - 102 WITH NON-NASA APPLICATIONS TRIPLED
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	364690	337289	226257	27401	111031	138432
2	168654	156237	111050	12416	45187	57603
3	104460	96919	72896	7541	24023	31564
4	73059	67883	53936	5175	13947	19123
5	54674	50869	42615	3804	8254	12058
6	42729	39806	35091	2922	4715	7637
7	34421	32105	29724	2316	2380	4696
8	28356	26477	25698	1878	779	2657
9	23764	22214	22562	1550	-348	1202
10	20190	18891	20047	1298	-1155	143
11	17344	16244	17982	1100	-1738	-637
12	15037	14095	16256	941	-2160	-1219
13	13137	12325	14791	811	-2465	-1653
14	11553	10848	13530	705	-2681	-1976
15	10218	9602	12434	616	-2832	-2216
16	9082	8541	11473	541	-2932	-2390
17	8108	7630	10623	477	-2993	-2515
18	7266	6843	9867	423	-3023	-2600
19	6534	6158	9189	376	-3031	-2655
20	5895	5559	8580	335	-3021	-2685

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 109 - BASELINE CASE C-1
SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	C	0	0	2059
1975	2344	10	28	0	0	2382
1976	2307	20	98	0	0	2425
1977	1876	192	459	111	556	3194
1978	1033	539	1037	248	1604	4461
1979	315	1014	1117	321	1665	4432
1980	0	825	1127	338	1251	3541
1981	0	406	1259	405	1222	3292
1982	0	13	1266	362	1277	2918
1983	0	0	1309	426	1258	2993
1984	0	0	913	397	1433	2743
1985	0	C	603	437	1276	2316
1986	0	0	468	398	1102	1968
1987	0	0	418	431	1186	2035
1988	0	0	366	413	1281	2060
1989	0	0	241	431	1238	1910
1990	0	0	64	417	537	1018
TOTAL	11434	3019	10773	5135	16886	47247

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 109 - BASELINE CASE C-1
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	401884	382380	262908	19503	119472	138975
2	185637	176756	127856	8881	48899	57780
3	114845	109428	83217	5416	26210	31627
4	80229	76499	61094	3730	15405	19135
5	59971	57222	47927	2748	9294	12043
6	46817	44701	39209	2115	5491	7607
7	37673	35994	33015	1678	2979	4657
8	31002	29640	28388	1362	1251	2614
9	25956	24831	24799	1124	31	1156
10	22030	21089	21934	941	-844	96
11	18907	18110	19592	797	-1481	-684
12	16377	15696	17642	680	-1945	-1264
13	14295	13709	15993	586	-2283	-1697
14	12561	12053	14580	508	-2527	-2019
15	11100	10657	13357	442	-2699	-2256
16	9858	9470	12288	387	-2817	-2429
17	8793	8452	11346	341	-2893	-2552
18	7874	7573	10510	301	-2937	-2635
19	7076	6809	9765	266	-2955	-2688
20	6379	6142	9096	237	-2953	-2716

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 110 - 109 WITH OSSA AND OMSF REDUCED BY 50 PERCENT
SPACE SHUTTLE SYSTEM
(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	20	53	0	0	2380
1977	1876	192	308	92	496	2964
1978	1033	539	693	208	1418	3891
1979	315	1014	666	283	1456	3734
1980	0	825	641	292	999	2757
1981	0	406	730	329	906	2371
1982	0	13	842	299	951	2105
1983	0	0	907	357	984	2248
1984	0	0	601	324	1108	2033
1985	0	0	345	358	954	1657
1986	0	0	243	322	834	1399
1987	0	0	210	356	857	1423
1988	0	0	183	335	923	1441
1989	0	0	121	352	893	1366
1990	0	0	32	328	375	735
TOTAL	11434	3019	6589	4235	13154	38431

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 110 - 109 WITH OSSA AND OMSF REDUCED BY 50 PERCENT
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	302945	287794	195557	15151	92237	107388
2	140166	133334	96813	6832	36520	43353
3	86855	82729	64051	4125	18678	22803
4	60772	57959	47729	2812	10230	13043
5	45497	43445	37954	2052	5490	7543
6	35570	34006	31435	1563	2571	4135
7	28664	27436	26767	1228	668	1896
8	23621	22634	23253	987	-618	368
9	19803	18995	20504	807	-1508	-701
10	16829	16160	18291	669	-2131	-1462
11	14461	13900	16468	561	-2568	-2007
12	12541	12066	14938	474	-2872	-2397
13	10959	10554	13634	405	-3080	-2675
14	9640	9292	12509	347	-3216	-2868
15	8528	8228	11527	300	-3299	-2999
16	7581	7321	10664	260	-3342	-3082
17	6769	6542	9898	227	-3355	-3128
18	6068	5869	9214	198	-3344	-3146
19	5458	5283	8600	174	-3316	-3142
20	4925	4771	8047	153	-3275	-3121

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA
SCENARIO 111 - BASELINE CASE C-3
SPACE SHUTTLE SYSTEM
(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	292	0	0	0	0	292
1973	1198	0	0	0	0	1198
1974	2027	0	0	0	0	2027
1975	2226	15	28	0	0	2269
1976	2127	30	98	0	0	2255
1977	1767	197	441	134	516	3055
1978	1008	537	973	329	1507	4354
1979	358	917	1062	468	1641	4446
1980	138	779	1062	447	1381	3807
1981	205	373	1183	442	1472	3675
1982	146	0	1215	449	1562	3372
1983	53	22	1271	502	1496	3344
1984	14	47	882	393	1550	2886
1985	0	46	558	460	1284	2348
1986	0	33	422	387	1095	1937
1987	0	13	400	441	1174	2028
1988	0	0	362	414	1268	2044
1989	0	0	241	437	1229	1907
1990	0	0	66	400	549	1015
TOTAL	11559	3009	10264	5703	17724	48259

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 111 - BASELINE CASE C-3

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	354694	337456	218431	17238	119024	136262
2	166452	158492	110168	7960	48323	56283
3	104424	99508	73846	4916	25661	30578
4	73849	70425	55514	3423	14911	18335
5	55796	53248	44387	2548	8860	11409
6	43966	41987	36871	1978	5115	7094
7	35666	34084	31429	1582	2655	4237
8	29558	28265	27290	1293	975	2268
9	24898	23824	24026	1074	-202	872
10	21245	20341	21382	903	-1041	-137
11	18317	17548	19193	768	-1644	-876
12	15928	15269	17349	659	-2080	-1420
13	13952	13382	15775	569	-2392	-1822
14	12296	11800	14414	495	-2614	-2118
15	10894	10461	13228	432	-2767	-2334
16	9697	9317	12185	380	-2868	-2488
17	8667	8332	11261	334	-2929	-2594
18	7774	7478	10438	296	-2960	-2663
19	6997	6734	9701	262	-2967	-2704
20	6316	6082	9038	233	-2956	-2722

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 112 - 111 WITH OSSA AND OMSF REDUCED BY 50 PERCENT

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	292	0	0	0	0	292
1973	1198	0	0	0	0	1198
1974	2027	0	0	0	0	2027
1975	2226	15	14	0	0	2255
1976	2127	30	53	0	0	2210
1977	1767	197	291	106	471	2832
1978	1008	537	641	267	1361	3814
1979	358	917	629	387	1448	3739
1980	138	779	604	381	1091	2993
1981	205	373	688	388	1095	2749
1982	146	0	814	385	1193	2538
1983	53	22	888	425	1189	2577
1984	14	47	586	323	1214	2184
1985	0	46	323	378	969	1716
1986	0	33	220	315	834	1402
1987	0	13	201	359	856	1429
1988	0	0	181	335	913	1429
1989	0	0	121	359	886	1366
1990	0	0	33	318	387	738
TOTAL	11559	3009	6287	4726	13907	39488

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 112 - 111 WITH OSSA AND OMSF REDUCED BY 50 PERCENT
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	267704	254154	163281	13550	90873	104423
2	125839	119658	84105	6181	35553	41734
3	79073	75301	57395	3772	17905	21677
4	56008	53411	43819	2596	9592	12188
5	42379	40469	35511	1910	4957	6867
6	33441	31974	29851	1467	2123	3590
7	27166	26005	25714	1160	291	1451
8	22543	21604	22540	938	-935	2
9	19013	18241	20016	771	-1774	-1002
10	16242	15600	17953	642	-2352	-1710
11	14020	13479	16231	541	-2751	-2210
12	12206	11746	14769	459	-3023	-2563
13	10702	10309	13512	393	-3202	-2809
14	9442	9103	12418	338	-3314	-2975
15	8374	8081	11457	293	-3376	-3083
16	7461	7206	10607	255	-3401	-3146
17	6675	6452	9850	222	-3398	-3175
18	5993	5798	9172	195	-3374	-3178
19	5399	5227	8561	171	-3334	-3162
20	4877	4726	8009	151	-3282	-3131

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

8A.2 Table 8.2 Data

The data contained within this section represent the Life-Cycle Cost Summaries and Cost-Effectiveness analyses for the two-stage shuttle and alternative configurations based upon internal NASA and contractor data. The data base contains all of the DoD missions, and is predicated upon 624 shuttle flights over the 1979 to 1990 operating period.

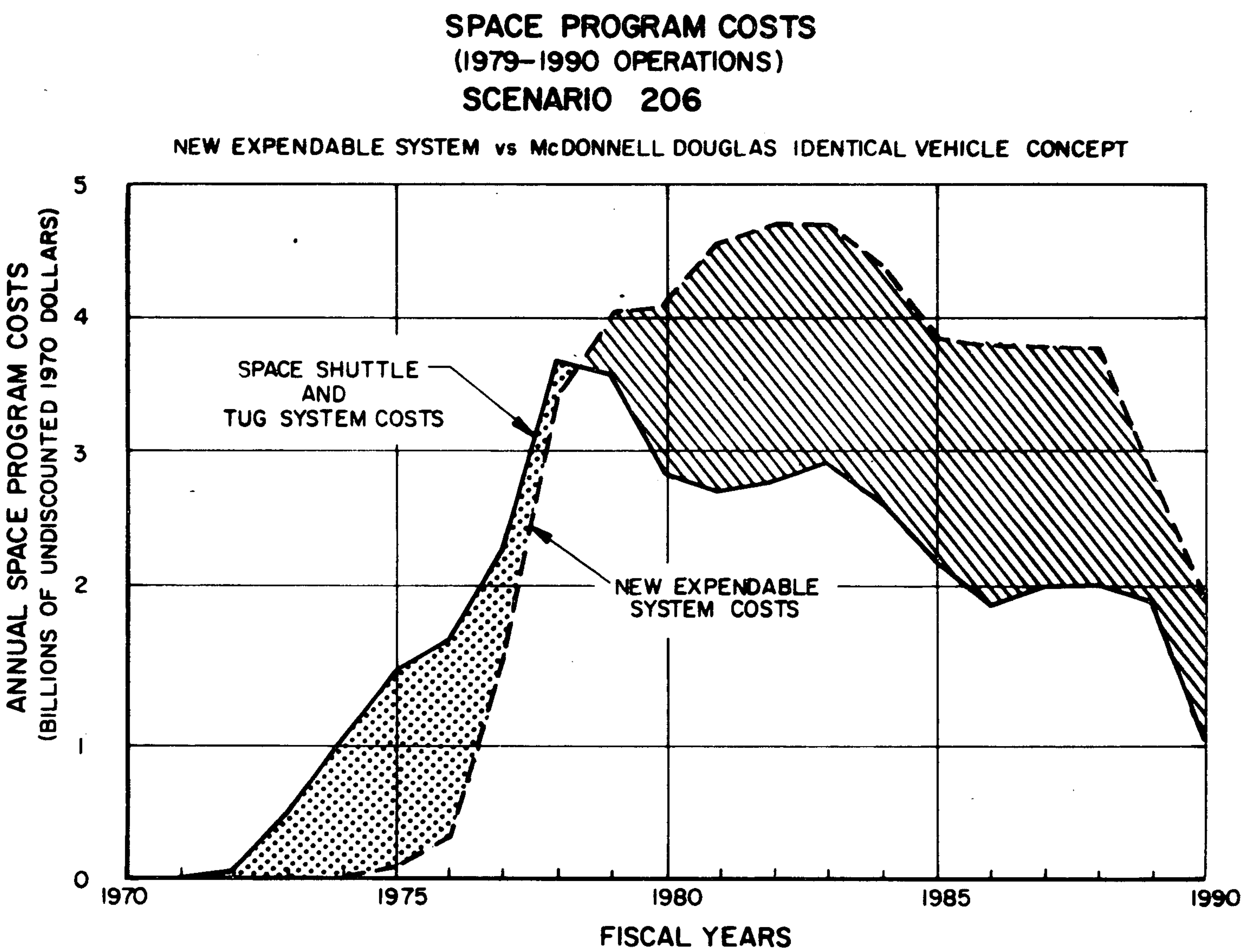


Figure 8A.2 Space Program Costs: New Expendable System Versus McDonnell Douglas Identical Vehicle Concept

LIFE CYCLE COST SUMMARY DATA

SCENARIO 200 - GRUMMAN TWO-STAGE, 1979 FOC

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

	NON-RECURRING COSTS			RECURRING COSTS		TOTAL
FISCAL YEAR	LAUNCH VEHICLE RDT&E	LAUNCH VEHICLE INVEST.	PAYLOAD RDT&E	LAUNCH	PAYLOAD	
1971	0	0	0	0	0	0
1972	62	0	0	0	0	62
1973	598	0	0	0	0	598
1974	1267	0	0	0	0	1267
1975	1838	10	28	0	0	1876
1976	1997	25	98	0	0	2120
1977	1600	25	450	107	533	2715
1978	1251	15	992	270	1547	4075
1979	772	0	1064	357	1648	3841
1980	328	0	1048	373	1210	2959
1981	37	0	1158	391	1158	2744
1982	15	0	1197	392	1219	2823
1983	0	0	1271	435	1215	2921
1984	0	0	881	390	1393	2664
1985	0	0	558	445	1226	2229
1986	0	0	422	411	1057	1890
1987	0	0	400	445	1150	1995
1988	0	0	362	424	1244	2030
1989	0	0	241	451	1205	1897
1990	0	0	66	410	525	1001
TOTAL	9765	75	10236	5301	16330	41707

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 200 - GRUMMAN TWO-STAGE, 1979 FOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	401884	381834	251361	20050	130472	150522
2	185637	176526	120458	9111	56067	65178
3	114845	109296	77327	5548	31969	37517
4	80229	76411	56042	3818	20369	24187
5	59971	57158	43440	2812	13718	16531
6	46817	44652	35143	2164	9508	11673
7	37673	35954	29285	1718	6669	8387
8	31002	29607	24937	1395	4669	6064
9	25956	24803	21588	1153	3215	4368
10	22030	21064	18930	966	2133	3100
11	18907	18088	16773	818	1315	2134
12	16377	15676	14989	700	687	1388
13	14295	13691	13489	603	202	806
14	12561	12037	12212	524	-175	348
15	11100	10643	11114	457	-471	-13
16	9858	9457	10159	401	-701	-300
17	8793	8440	9322	353	-882	-528
18	7874	7562	8584	312	-1022	-709
19	7076	6799	7929	277	-1129	-852
20	6379	6132	7344	246	-1211	-964

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 201 - GRUMMAN RS1C, 1982 FOC

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

	NON-RECURRING COSTS			RECURRING COSTS		TOTAL
FISCAL YEAR	LAUNCH VEHICLE RDT&E	LAUNCH VEHICLE INVEST.	PAYLOAD RDT&E	LAUNCH	PAYLOAD	
1971	0	0	0	0	0	0
1972	62	0	0	0	0	62
1973	458	0	0	0	0	458
1974	942	0	0	0	0	942
1975	1543	10	28	0	0	1581
1976	1637	25	98	0	0	1760
1977	1355	25	450	107	533	2470
1978	1266	15	992	270	1547	4090
1979	841	0	1064	357	1648	3910
1980	558	0	1048	373	1210	3189
1981	43	0	1158	391	1158	2750
1982	15	0	1197	392	1219	2823
1983	0	0	1271	435	1215	2921
1984	0	0	881	390	1393	2664
1985	0	0	558	445	1226	2229
1986	0	0	422	411	1057	1890
1987	0	0	400	445	1150	1995
1988	0	0	362	424	1244	2030
1989	0	0	241	451	1205	1897
1990	0	0	66	410	525	1001
TOTAL	8720	75	10236	5301	16330	40662

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 201 - GRUMMAN RS1C, 1979 EOC
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	401884	381834	250355	20050	131478	151528
2	185637	176526	119490	9111	57036	66147
3	114845	109296	76395	5548	32901	38449
4	80229	76411	55145	3818	21265	25083
5	59971	57158	42577	2812	14581	17394
6	46817	44652	34313	2164	10339	12504
7	37673	35954	28486	1718	7468	9186
8	31002	29607	24168	1395	5438	6833
9	25956	24803	20848	1153	3955	5108
10	22030	21064	18218	966	2846	3812
11	18907	18088	16088	818	2000	2819
12	16377	15676	14329	700	1347	2048
13	14295	13691	12853	603	837	1441
14	12561	12037	11600	524	436	960
15	11100	10643	10524	457	118	575
16	9858	9457	9591	401	-133	267
17	8793	8440	8775	353	-334	18
18	7874	7562	8056	312	-494	-182
19	7076	6799	7420	277	-621	-343
20	6379	6132	6853	246	-721	-474

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 202 - GRUMMAN RS1C, 1982 FOC
SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS: LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS: LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS: PAYLOAD RDT&E	RECURRING COSTS: LAUNCH	RECURRING COSTS: PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	60	0	0	0	0	60
1973	390	0	0	0	0	390
1974	780	0	0	0	0	780
1975	1092	0	0	0	0	1092
1976	1078	0	0	0	0	1078
1977	937	0	0	0	0	937
1978	968	10	28	0	0	1006
1979	1003	25	98	89	0	1215
1980	923	25	450	196	533	2127
1981	723	15	992	359	1547	3636
1982	479	0	1064	325	1648	3516
1983	209	0	1048	341	1210	2808
1984	46	0	1158	359	1158	2721
1985	33	0	1197	360	1219	2809
1986	13	0	1271	403	1215	2902
1987	0	0	881	358	1393	2632
1988	0	0	558	413	1226	2197
1989	0	0	422	379	1057	1858
1990	0	0	400	413	1150	1963
TOTAL	8734	75	9567	3995	13356	35727

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 202 - GRUMMAN RS1C, 1982 FOC
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	431422	410609	269491	20812	141118	161930
2	193210	183991	124468	9219	59522	68741
3	115759	110298	77040	5461	33257	38718
4	78261	74611	53883	3649	20727	24377
5	56591	53983	40356	2607	13627	16234
6	42731	40785	31590	1945	9195	11140
7	33260	31765	25511	1495	6254	7749
8	26481	25306	21085	1175	4220	5396
9	21458	20518	17745	940	2772	3712
10	17634	16871	15152	762	1719	2482
11	14660	14034	13092	625	942	1568
12	12307	11788	11425	518	362	881
13	10417	9984	10056	432	-72	360
14	8880	8516	8916	364	-399	-35
15	7617	7309	7955	307	-646	-338
16	6570	6308	7139	261	-830	-568
17	5695	5471	6438	223	-967	-743
18	4958	4766	5833	192	-1066	-874
19	4334	4168	5306	165	-1137	-972
20	3801	3658	4844	143	-1185	-1042

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 203 - GRUMMAN RS1C, 1983 FOC
SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

	NON-RECURRING COSTS			RECURRING COSTS		TOTAL
FISCAL YEAR	LAUNCH VEHICLE RDT&E	LAUNCH VEHICLE INVEST.	PAYLOAD RDT&E	LAUNCH	PAYLOAD	
1971	0	0	0	0	0	0
1972	60	0	0	0	0	60
1973	270	0	0	0	0	270
1974	560	0	0	0	0	560
1975	680	0	0	0	0	680
1976	772	0	0	0	0	772
1977	888	0	0	0	0	888
1978	917	0	0	0	0	917
1979	1008	10	28	76	0	1122
1980	1087	25	98	76	0	1286
1981	1040	25	450	183	533	2231
1982	881	15	992	346	1547	3781
1983	591	0	1064	312	1648	3615
1984	305	0	1048	328	1210	2891
1985	46	0	1158	346	1158	2708
1986	33	0	1197	347	1219	2796
1987	13	0	1271	390	1215	2889
1988	0	0	881	345	1393	2619
1989	0	0	558	400	1226	2184
1990	0	0	422	366	1057	1845
TOTAL	9151	75	9167	3515	12206	34114

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 203 - GRUMMAN RSIC, 1983 FOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	435071	414091	276546	20979	137544	158524
2	192859	183662	126435	9197	57226	66424
3	114358	108967	77449	5391	31517	36908
4	76511	72947	53604	3564	19342	22907
5	54751	52231	39727	2519	12504	15023
6	40913	39054	30776	1859	8277	10137
7	31517	30103	24598	1414	5505	6919
8	24837	23737	20126	1099	3611	4711
9	19922	19051	16771	870	2280	3151
10	16208	15509	14182	698	1327	2026
11	13341	12774	12139	567	635	1202
12	11090	10625	10497	465	128	593
13	9297	8912	9157	384	-244	140
14	7850	7530	8049	320	-518	-198
15	6671	6403	7122	268	-718	-450
16	5701	5476	6339	225	-863	-637
17	4897	4706	5672	191	-966	-775
18	4225	4063	5100	162	-1037	-874
19	3661	3522	4606	138	-1083	-944
20	3183	3065	4175	118	-1110	-991

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA
SCENARIO 204 - GRUMMAN TAHO, 1979 FOC
SPACE SHUTTLE SYSTEM
(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	62	0	0	0	0	62
1973	398	0	0	0	0	398
1974	757	0	0	0	0	757
1975	1108	10	28	0	0	1146
1976	1251	25	98	0	0	1374
1977	1080	25	450	107	533	2195
1978	801	15	992	270	1547	3625
1979	611	0	1064	423	1648	3746
1980	207	0	1048	574	1210	3039
1981	37	0	1158	670	1158	3023
1982	15	0	1197	677	1219	3108
1983	0	0	1271	771	1215	3257
1984	0	0	881	686	1393	2960
1985	0	0	558	808	1226	2592
1986	0	0	422	712	1057	2191
1987	0	0	400	808	1150	2358
1988	0	0	362	753	1244	2359
1989	0	0	241	786	1205	2232
1990	0	0	66	728	525	1319
TOTAL	6327	75	10236	8773	16330	41741

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 204 - GRUMMAN TAHO, 1979 FOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT RATE	1970 PRESENT VALUES CE	NE	SH	COST DIFFERENCES CE-NE	NE-SH	CE-SH
1	401884	381834	277501	20050	104332	124382
2	185637	176526	130706	9111	45819	54930
3	114845	109296	82496	5548	26800	32348
4	80229	76411	58814	3818	17597	21415
5	59971	57158	44873	2812	12284	15097
6	46817	44652	35758	2164	8893	11058
7	37673	35954	29372	1718	6582	8301
8	31002	29607	24671	1395	4935	6331
9	25956	24803	21080	1153	3722	4875
10	22030	21064	18258	966	2806	3772
11	18907	18088	15988	818	2100	2919
12	16377	15676	14128	700	1548	2249
13	14295	13691	12579	603	1112	1716
14	12561	12037	11273	524	763	1287
15	11100	10643	10159	457	483	940
16	9858	9457	9200	401	257	658
17	8793	8440	8367	353	73	426
18	7874	7562	7638	312	-76	235
19	7076	6799	6997	277	-198	78
20	6379	6132	6430	246	-297	-50

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 205 - MCDC RATO, 1979 FOC

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

	NON-RECURRING COSTS			RECURRING COSTS		TOTAL
FISCAL YEAR	LAUNCH VEHICLE RDT&E	LAUNCH VEHICLE INVEST.	PAYLOAD RDT&E	LAUNCH	PAYLOAD	
1971	0	0	0	0	0	0
1972	73	0	0	0	0	73
1973	467	0	0	0	0	467
1974	885	0	0	0	0	885
1975	1221	10	28	0	0	1259
1976	1424	25	98	0	0	1547
1977	1222	25	450	107	533	2337
1978	772	15	992	270	1547	3596
1979	279	0	1064	400	1648	3391
1980	158	0	1048	505	1210	2921
1981	37	0	1158	575	1158	2928
1982	15	0	1197	580	1219	3011
1983	0	0	1271	664	1215	3150
1984	0	0	881	585	1393	2859
1985	0	0	558	685	1226	2469
1986	0	0	422	610	1057	2089
1987	0	0	400	685	1150	2235
1988	0	0	362	641	1244	2247
1989	0	0	241	672	1205	2118
1990	0	0	66	620	525	1211
TOTAL	6553	75	10236	7599	16330	40793

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPRCACH
SCENARIO 205 - MCDC RATO, 1979 FOC
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT RATE	1970 PRESENT VALUES CE	NE	SH	COST DIFFERENCES CE-NE	NE-SH	CE-SH
1	401884	381834	267820	20050	114014	134064
2	185637	176526	126449	9111	50077	59188
3	114845	109296	80010	5548	29286	34834
4	80229	76411	57190	3818	19221	23039
5	59971	57158	43750	2812	13408	16220
6	46817	44652	34956	2164	9695	11860
7	37673	35954	28789	1718	7165	8883
8	31002	29607	24246	1395	5360	6756
9	25956	24803	20771	1153	4031	5184
10	22030	21064	18037	966	3027	3993
11	18907	18088	15835	818	2253	3072
12	16377	15676	14028	700	1648	2349
13	14295	13691	12521	603	1170	1774
14	12561	12037	11248	524	788	1312
15	11100	10643	10161	457	481	939
16	9858	9457	9223	401	233	634
17	8793	8440	8407	353	32	385
18	7874	7562	7693	312	-130	181
19	7076	6799	7063	277	-264	13
20	6379	6132	6504	246	-372	-125

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

F

LIFE CYCLE COST SUMMARY DATA

SCENARIO 206 - MCDC, IVC, 1979 FOC SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS: LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS: LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS: PAYLOAD RDT&E	RECURRING COSTS: LAUNCH	RECURRING COSTS: PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	62	0	0	0	0	62
1973	488	0	0	0	0	488
1974	1026	0	0	0	0	1026
1975	1521	10	28	0	0	1559
1976	1676	25	98	0	0	1799
1977	1354	25	450	107	533	2469
1978	1074	15	992	270	1547	3898
1979	677	0	1064	393	1648	3782
1980	296	0	1048	487	1210	3041
1981	37	0	1158	549	1158	2902
1982	15	0	1197	554	1219	2985
1983	0	0	1271	632	1215	3118
1964	0	0	881	558	1393	2832
1985	0	0	558	652	1226	2436
1986	0	0	422	582	1057	2061
1987	0	0	400	652	1150	2202
1988	0	0	362	611	1244	2217
1989	0	0	241	642	1205	2088
1990	0	0	66	591	525	1182
TOTAL	8226	75	10236	7280	16330	42147

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 206 - MCDC IVC, 1979 FOC
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT RATE	1970 PRESENT VALUES CE	NE	SH	COST DIFFERENCES CE-NE	NE-SH	CE-SH
1	401884	381834	266695	20050	115138	135188
2	185637	176526	126687	9111	49838	58950
3	114845	109296	80631	5548	28664	34213
4	80229	76411	57956	3818	18454	22272
5	59971	57158	44570	2812	12587	15400
6	46817	44652	35788	2164	8863	11028
7	37673	35954	29612	1718	6342	8060
8	31002	29607	25047	1395	4559	5954
9	25956	24803	21546	1153	3257	4410
10	22030	21064	18781	966	2283	3249
11	18907	18088	16547	818	1541	2360
12	16377	15676	14707	700	969	1669
13	14295	13691	13169	603	522	1126
14	12561	12037	11865	524	171	695
15	11100	10643	10748	457	-105	351
16	9858	9457	9782	401	-324	76
17	8793	8440	8939	353	-498	-145
18	7874	7562	8198	312	-636	-323
19	7076	6799	7544	277	-744	-467
20	6379	6132	6962	246	-829	-582

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 207 - MCDC HO/1, 1983 FOC
SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	50	0	0	0	0	50
1973	390	0	0	0	0	390
1974	675	0	0	0	0	675
1975	800	0	0	0	0	800
1976	802	0	0	0	0	802
1977	1008	0	0	0	0	1008
1978	1257	0	0	0	0	1257
1979	1338	10	28	76	0	1452
1980	1327	25	98	76	0	1526
1981	1260	25	450	183	533	2471
1982	1187	15	992	346	1547	4087
1983	1171	0	1064	312	1648	4195
1984	819	0	1048	328	1210	3405
1985	46	0	1158	346	1158	2708
1986	33	0	1197	347	1219	2796
1987	13	0	1271	390	1215	2889
1988	0	0	881	345	1393	2619
1989	0	0	558	400	1226	2184
1990	0	0	422	366	1057	1845
TOTAL	12196	75	9167	3515	12206	37159

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 207 - MCDC HO/1, 1983 FOC
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	435071	414091	279294	20979	134796	155776
2	192859	183662	128920	9197	54741	63939
3	114358	108967	79701	5391	29265	34657
4	76511	72947	55648	3564	17298	20863
5	54751	52231	41586	2519	10644	13164
6	40913	39054	32470	1859	6583	8443
7	31517	30103	26145	1414	3958	5372
8	24837	23737	21541	1099	2196	3296
9	19922	19051	18067	870	984	1855
10	16208	15509	15371	698	137	836
11	13341	12774	13233	567	-458	108
12	11090	10625	11504	465	-879	-413
13	9297	8912	10086	384	-1173	-789
14	7850	7530	8907	320	-1377	-1057
15	6671	6403	7917	268	-1513	-1245
16	5701	5476	7076	225	-1600	-1374
17	4897	4706	6357	191	-1650	-1459
18	4225	4063	5736	162	-1673	-1510
19	3661	3522	5198	138	-1675	-1537
20	3183	3065	4728	118	-1663	-1544

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA
SCENARIO 208 - MCDC TWO-STAGE, 1979 FOC
SPACE SHUTTLE SYSTEM
(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS			RECURRING COSTS		TOTAL
	LAUNCH VEHICLE RDT&E	LAUNCH VEHICLE INVEST.	PAYLOAD RDT&E	LAUNCH	PAYLOAD	
1971	0	0	0	0	0	0
1972	102	0	0	0	0	102
1973	708	0	0	0	0	708
1974	1437	0	0	0	0	1437
1975	1788	10	28	0	0	1826
1976	1927	25	98	0	0	2050
1977	2040	25	450	107	533	3155
1978	2001	15	992	270	1547	4825
1979	1471	0	1064	357	1648	4540
1980	633	0	1048	373	1210	3264
1981	37	0	1158	391	1158	2744
1982	15	0	1197	392	1219	2823
1983	0	0	1271	435	1215	2921
1984	0	0	881	390	1393	2664
1985	0	0	558	445	1226	2229
1986	0	0	422	411	1057	1890
1987	0	0	400	445	1150	1995
1988	0	0	362	424	1244	2030
1989	0	0	241	451	1205	1897
1990	0	0	66	410	525	1001
TOTAL	12159	75	10236	5301	16330	44101

COST EFFECTIVENESS ANALYSIS + EQUAL CAPABILITY APPROACH
SCENARIO 208 - MCDC TWO-STAGE, 1979 FOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	401884	381834	253575	20050	128258	148308
2	185637	176526	122508	9111	54017	63128
3	114845	109296	79227	5548	30069	35617
4	80229	76411	57805	3818	18605	22423
5	59971	57158	45078	2812	12080	14893
6	46817	44652	36666	2164	7985	10150
7	37673	35954	30703	1718	5251	6970
8	31002	29607	26259	1395	3347	4743
9	25956	24803	22820	1153	1982	3135
10	22030	21064	20081	966	982	1949
11	18907	16088	17849	818	239	1058
12	16377	15676	15995	700	-318	381
13	14295	13691	14432	603	-740	-136
14	12561	12037	13096	524	-1059	-535
15	11100	10643	11943	457	-1300	-843
16	9858	9457	10938	401	-1480	-1079
17	8793	8440	10054	353	-1614	-1261
18	7874	7562	9273	312	-1711	-1398
19	7076	6799	8578	277	-1778	-1501
20	6379	6132	7956	246	-1823	-1576

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 209 - INTERNAL NASA TWO-STAGE, 1979 FOC SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS: LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS: LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS: PAYLOAD RDT&E	RECURRING COSTS: LAUNCH	RECURRING COSTS: PAYLOAD	TOTAL
1971	4	0	0	0	0	4
1972	72	0	0	0	0	72
1973	421	0	0	0	0	421
1974	1084	0	0	0	0	1084
1975	1786	10	28	0	0	1824
1976	2167	25	98	0	0	2290
1977	2011	25	450	107	533	3126
1978	1526	15	992	270	1547	4350
1979	695	0	1064	357	1648	3764
1980	221	0	1048	373	1210	2852
1981	53	0	1158	391	1158	2760
1982	15	0	1197	392	1219	2823
1983	0	0	1271	435	1215	2921
1984	0	0	881	390	1393	2664
1985	0	0	558	445	1226	2229
1986	0	0	422	411	1057	1890
1987	0	0	400	445	1150	1995
1988	0	0	362	424	1244	2030
1989	0	0	241	451	1205	1897
1990	0	0	66	410	525	1001
TOTAL	10055	75	10236	5301	16330	41997

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 209 - INTERNAL NASA TWO-STAGE, 1979 FOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT RATE	1970 PRESENT VALUES CE	NE	SH	COST DIFFERENCES CE-NE	NE-SH	CE-SH
1	401884	381834	251622	20050	130211	150261
2	185637	176526	120693	9111	55833	64944
3	114845	109296	77537	5548	31758	37307
4	80229	76411	56230	3818	20180	23998
5	59971	57158	43607	2812	13550	16363
6	46817	44652	35292	2164	9359	11524
7	37673	35954	29417	1718	6537	8256
8	31002	29607	25054	1395	4553	5948
9	25956	24803	21689	1153	3113	4266
10	22030	21064	19019	966	2045	3011
11	18907	18088	16850	818	1238	2057
12	16377	15676	15054	700	622	1322
13	14295	13691	13544	603	147	751
14	12561	12037	12258	524	-221	302
15	11100	10643	11151	457	-508	-50
16	9858	9457	10188	401	-731	-330
17	8793	8440	9344	353	-904	-551
18	7874	7562	8600	312	-1037	-725
19	7076	6799	7938	277	-1139	-862
20	6379	6132	7348	246	-1215	-969

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 210 - INTERNAL NASA TWO-STAGE, 1979 FOC, 1985 TUG

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	4	0	0	0	0	4
1972	70	0	0	0	0	70
1973	413	0	0	0	0	413
1974	1052	0	0	0	0	1052
1975	1725	15	28	0	0	1768
1976	2044	30	98	0	0	2172
1977	1997	25	441	134	516	3113
1978	1415	20	973	329	1507	4244
1979	737	10	1062	468	1641	3918
1980	289	0	1062	447	1381	3179
1981	221	0	1183	442	1472	3318
1982	146	0	1215	449	1562	3372
1983	75	0	1271	502	1496	3344
1984	61	0	882	393	1550	2886
1985	46	0	558	460	1284	2348
1986	33	0	422	387	1095	1937
1987	13	0	400	441	1174	2028
1988	0	0	362	414	1268	2044
1989	0	0	241	437	1229	1907
1990	0	0	66	400	549	1015
TOTAL	10341	100	10264	5703	17724	44132

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPRCACH
SCENARIO 210 - INTERNAL NASA TWO-STAGE, 1979 FOC, 1985 TUG
(TOTAL PRCGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT RATE	1970 PRESENT VALUES CE	NE	SH	COST DIFFERENCES CE-NE	NE-SH	CE-SH
1	375785	357310	207045	18475	150264	168739
2	175027	166563	103455	8463	63108	71572
3	109082	103892	68729	5189	35163	40352
4	76701	73110	51226	3591	21883	25474
5	57062	55004	40623	2657	14380	17038
6	45240	43186	33478	2053	9707	11761
7	36563	34928	28318	1635	6609	8244
8	30203	28872	24407	1330	4465	5796
9	25371	24269	21333	1101	2936	4038
10	21596	20671	18851	924	1820	2745
11	18581	17796	16804	784	992	1777
12	16129	15458	15086	671	371	1042
13	14105	13526	13625	578	-98	480
14	12414	11912	12368	502	-456	46
15	10986	10548	11276	438	-728	-290
16	9769	9385	10320	384	-935	-550
17	8723	8385	9476	338	-1091	-753
18	7819	7520	8728	298	-1207	-908
19	7032	6767	8061	265	-1293	-1028
20	6344	6108	7463	235	-1354	-1118

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA
SCENARIO 211 - INTERNAL NASA TWO-STAGE, 1985 IOC
SPACE SHUTTLE SYSTEM
(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	0	0	0	0	0	0
1973	100	0	0	0	0	100
1974	100	0	0	0	0	100
1975	100	0	0	0	0	100
1976	104	0	0	0	0	104
1977	72	0	0	0	0	72
1978	421	0	0	0	0	421
1979	1084	0	0	0	0	1084
1980	1786	0	0	0	0	1786
1981	2152	0	28	0	0	2180
1982	1991	0	98	0	0	2089
1983	1510	0	450	107	533	2600
1984	779	0	992	270	1547	3588
1985	287	0	1064	236	1648	3235
1986	49	0	1048	252	1210	2559
1987	13	0	1158	270	1158	2599
1988	0	0	1197	271	1219	2687
1989	0	0	1271	314	1215	2800
1990	0	0	881	269	1393	2543
TOTAL	10548	0	8187	1989	9923	30647

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 211 - INTERNAL NASA TWO-STAGE, 1985 IOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	386509	364931	243864	21577	121067	142645
2	169325	160050	111310	9274	48739	58014
3	99140	93811	67918	5329	25892	31222
4	65446	61993	46728	3453	15265	18718
5	46179	43787	34363	2392	9424	11816
6	34008	32278	26371	1729	5906	7636
7	25807	24517	20852	1289	3665	4955
8	20026	19043	16856	982	2186	3169
9	15812	15049	13863	762	1186	1948
10	12660	12060	11559	599	501	1101
11	10254	9776	9747	477	29	507
12	8386	8002	8297	383	-295	88
13	6915	6604	7121	311	-516	-205
14	5744	5490	6154	254	-664	-410
15	4801	4592	5351	208	-759	-550
16	4035	3863	4679	172	-816	-643
17	3409	3266	4111	143	-845	-701
18	2893	2774	3628	119	-854	-734
19	2466	2365	3215	100	-849	-749
20	2109	2025	2859	84	-834	-750

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 212 - INTERNAL NASA TWO-STAGE, PHASED DEVELOPMENT, 1985 IOC

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	4	0	0	0	0	4
1972	63	0	0	0	0	63
1973	318	0	0	0	0	318
1974	743	0	0	0	0	743
1975	1088	0	0	0	0	1088
1976	1158	0	0	0	0	1158
1977	1006	0	0	0	0	1006
1978	923	0	0	0	0	923
1979	951	0	0	0	0	951
1980	1074	0	0	0	0	1074
1981	1302	0	28	0	0	1330
1982	1244	0	98	0	0	1342
1983	1026	0	450	107	533	2116
1984	534	0	992	270	1547	3343
1985	190	0	1064	236	1648	3138
1986	33	0	1048	252	1210	2543
1987	13	0	1158	270	1158	2599
1988	0	0	1197	271	1219	2687
1989	0	0	1271	314	1215	2800
1990	0	0	881	269	1393	2543
TOTAL	11670	0	8187	1989	9923	31769

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 212 - INTERNAL NASA TWO-STAGE, PHASED DEVELOPMENT, 1985 IOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT RATE	1970 PRESENT VALUES CE	NE	SH	COST DIFFERENCES CE-NE	NE-SH	CE-SH
1	386509	364931	245100	21577	119831	141408
2	169325	160056	112635	9274	47414	56689
3	99140	93811	69309	5329	24501	29830
4	65446	61993	48167	3453	13825	17278
5	46179	43787	35835	2392	7952	10344
6	34008	32278	27864	1729	4414	6144
7	25807	24517	22353	1289	2164	3453
8	20026	19043	18359	982	684	1667
9	15812	15049	15358	762	-308	453
10	12660	12060	13041	599	-980	-380
11	10254	9776	11211	477	-1435	-957
12	8386	8002	9740	383	-1738	-1354
13	6915	6604	8539	311	-1934	-1623
14	5744	5490	7545	254	-2054	-1800
15	4801	4592	6713	208	-2120	-1911
16	4035	3863	6009	172	-2146	-1973
17	3409	3266	5410	143	-2143	-2000
18	2893	2774	4894	119	-2120	-2001
19	2466	2365	4448	100	-2082	-1982
20	2109	2025	4060	84	-2034	-1950

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

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LIFE CYCLE COST SUMMARY DATA

SCENARIO 213 - INTERNAL NASA PHASED MINITECH, 1985 IOC

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	4	0	0	0	0	4
1972	12	0	0	0	0	12
1973	201	0	0	0	0	201
1974	508	0	0	0	0	508
1975	704	0	0	0	0	704
1976	756	0	0	0	0	756
1977	775	0	0	0	0	775
1978	256	0	0	0	0	256
1979	1082	0	0	0	0	1082
1980	1342	0	0	0	0	1342
1981	1476	0	28	0	0	1504
1982	1286	0	98	0	0	1384
1983	997	0	450	107	533	2087
1984	543	0	992	270	1547	3352
1985	204	0	1064	236	1648	3152
1986	45	0	1048	252	1210	2555
1987	13	0	1158	270	1158	2599
1988	17	0	1197	271	1219	2704
1989	0	0	1271	314	1215	2800
1990	0	0	881	269	1393	2543
TOTAL	10221	0	8187	1939	9923	30320

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 213 - INTERNAL NASA PHASED MINITECH, 1985 IOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT RATE	1970 PRESENT VALUES CE	NE	SH	COST DIFFERENCES CE-NE	NE-SH	CE-SH
1	386509	364931	243710	21577	121221	142799
2	169325	160050	111302	9274	48748	58022
3	99140	93811	68030	5329	25780	31109
4	65446	61993	46942	3453	15051	18504
5	46179	43787	34661	2392	9126	11518
6	34008	32278	26738	1729	5539	7269
7	25807	24517	21274	1289	3242	4532
8	20026	19043	17325	982	1717	2700
9	15812	15049	14367	762	681	1444
10	12660	12060	12092	599	-31	568
11	10254	9776	10301	477	-524	-47
12	8386	8002	8868	383	-865	-481
13	6915	6604	7702	311	-1097	-786
14	5744	5490	6742	254	-1252	-998
15	4801	4592	5943	208	-1350	-1141
16	4035	3863	5271	172	-1407	-1235
17	3409	3266	4701	143	-1434	-1291
18	2893	2774	4214	119	-1439	-1320
19	2466	2365	3795	100	-1429	-1328
20	2109	2025	3432	84	-1406	-1322

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

8A. 3 Table 8. 3 Data

The data contained within this section represent the Life-Cycle Cost Summaries and Cost-Effectiveness analyses for the alternative configurations based upon contractor data. The data base excludes some of the DoD missions, and is predicated upon 514 shuttle flights over the 1979 to 1990 operating period.

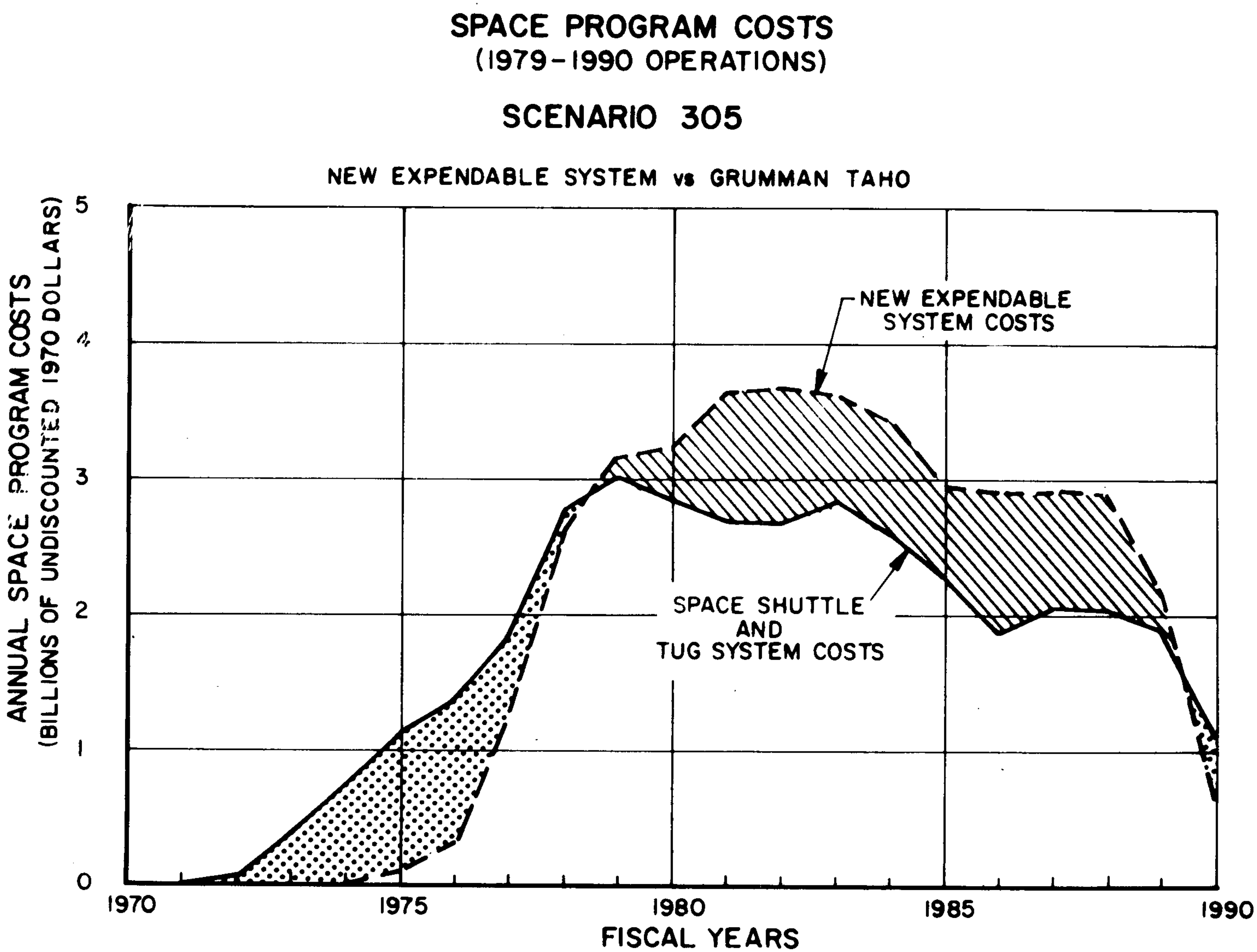

Figure 8A.3 Space Program Costs: New Expendable System Versus Grumman TAHO

LIFE CYCLE COST SUMMARY DATA
SCENARIO 300 - GRUMMAN TWO-STAGE, 1979 IOC
SPACE SHUTTLE SYSTEM
(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	62	0	0	0	0	62
1973	598	0	0	0	0	598
1974	1267	0	0	0	0	1267
1975	1838	10	28	0	0	1876
1976	1997	25	90	0	0	2112
1977	1600	25	411	78	252	2366
1978	1251	15	944	207	814	3231
1979	772	0	1049	283	975	3079
1980	328	0	1048	277	1128	2781
1981	37	0	1136	293	960	2426
1982	15	0	1089	296	1021	2421
1983	0	0	1104	338	1057	2499
1984	0	0	841	293	1195	2329
1985	0	0	558	348	1028	1934
1986	0	0	422	314	859	1595
1987	0	0	400	349	952	1701
1988	0	0	362	326	1038	1726
1989	0	0	241	355	989	1585
1990	0	0	66	312	419	797
TOTAL	9765	75	9789	4069	12687	36385

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 300 - GRUMMAN TWO-STAGE, 1979 IOC
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	314130	294674	211153	19456	83521	102977
2	145181	136325	101850	8856	34475	43331
3	89864	84464	65774	5399	18690	24089
4	62809	59091	47931	3717	11160	14877
5	46971	44232	37339	2739	6893	9632
6	36684	34576	30346	2108	4230	6338
7	29531	27859	25393	1672	2465	4137
8	24311	22954	21707	1357	1247	2604
9	20361	19241	18858	1120	382	1503
10	17287	16349	16591	937	-242	695
11	14841	14047	14746	793	-699	94
12	12858	12179	13215	678	-1035	-357
13	11226	10642	11925	583	-1282	-696
14	9866	9360	10824	505	-1463	-957
15	8720	8279	9874	440	-1594	-1153
16	7746	7360	9047	386	-1686	-1300
17	6911	6571	8320	339	-1748	-1409
18	6189	5890	7678	299	-1788	-1488
19	5563	5297	7106	265	-1809	-1543
20	5015	4779	6595	235	-1815	-1579

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 301 - MCDC TWO-STAGE, 1979 IOC
SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	102	0	0	0	0	102
1973	708	0	0	0	0	708
1974	1437	0	0	0	0	1437
1975	1788	10	28	0	0	1826
1976	1927	25	90	0	0	2042
1977	2040	25	411	78	252	2806
1978	2001	15	944	207	814	3981
1979	1471	0	1049	283	975	3778
1980	633	0	1048	277	1128	3086
1981	37	0	1136	293	960	2426
1982	15	0	1089	296	1021	2421
1983	0	0	1104	338	1057	2499
1984	0	0	841	293	1195	2329
1985	0	0	558	348	1028	1934
1986	0	0	422	314	859	1595
1987	0	0	400	349	952	1701
1988	0	0	362	326	1038	1726
1989	0	0	241	355	989	1585
1990	0	0	66	312	419	797
TOTAL	12159	75	9789	4069	12687	38779

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 301 - MCDC TWO-STAGE, 1979 IOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	314130	294674	213367	19456	81307	100763
2	145181	136325	103900	8856	32425	41281
3	89864	84464	67674	5399	16790	22189
4	62809	59091	49694	3717	9397	13114
5	46971	44232	38977	2739	5255	7994
6	36684	34576	31869	2108	2707	4815
7	29531	27859	26811	1672	1047	2719
8	24311	22954	23028	1357	-74	1282
9	20361	19241	20090	1120	-849	270
10	17287	16349	17742	937	-1393	-455
11	14841	14047	15822	793	-1774	-981
12	12858	12179	14221	678	-2041	-1363
13	11226	10642	12868	583	-2225	-1641
14	9866	9360	11708	505	-2347	-1841
15	8720	8279	10703	440	-2423	-1983
16	7746	7360	9826	386	-2465	-2079
17	6911	6571	9052	339	-2481	-2141
18	6189	5890	8367	299	-2477	-2177
19	5563	5297	7755	265	-2458	-2192
20	5015	4779	7207	235	-2427	-2191

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 302 - INTERNAL NASA TWO-STAGE, 1979 IOC
SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

	NON-RECURRING COSTS			RECURRING COSTS		TOTAL
FISCAL YEAR	LAUNCH VEHICLE RDT&E	LAUNCH VEHICLE INVEST.	PAYLOAD RDT&E	LAUNCH	PAYLOAD	
1971	4	0	0	0	0	4
1972	72	0	0	0	0	72
1973	421	0	0	0	0	421
1974	1084	0	0	0	0	1084
1975	1786	10	28	0	0	1824
1976	2167	25	90	0	0	2282
1977	2011	25	411	78	252	2777
1978	1526	15	944	207	814	3506
1979	695	0	1049	340	975	3059
1980	221	0	1048	334	1128	2731
1981	53	0	1136	350	960	2499
1982	15	0	1089	353	1021	2478
1983	0	0	1104	395	1057	2556
1984	0	0	841	350	1195	2386
1985	0	0	558	405	1028	1991
1986	0	0	422	371	859	1652
1987	0	0	400	406	952	1758
1988	0	0	362	383	1036	1783
1989	0	0	241	412	989	1642
1990	0	0	66	369	419	854
TOTAL	10055	75	9789	4753	12687	37359

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPRCACH

SCENARIO 302 - INTERNAL NASA TWO-STAGE, 1979 IOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	314130	294674	216609	19456	78065	97521
2	145181	136325	104469	8856	31856	40712
3	89864	84464	67447	5399	17016	22416
4	62809	59091	49131	3717	9960	13677
5	46971	44232	38254	2739	5977	8716
6	36684	34576	31071	2108	3504	5612
7	29531	27859	25983	1672	1875	3547
8	24311	22954	22195	1357	758	2115
9	20361	19241	19267	1120	-26	1094
10	17287	16349	16937	937	-587	350
11	14841	14047	15040	793	-992	-199
12	12858	12179	13466	678	-1286	-608
13	11226	10642	12140	583	-1497	-913
14	9866	9360	11008	505	-1648	-1142
15	8720	8279	10032	440	-1752	-1311
16	7746	7360	9182	386	-1821	-1435
17	6911	6571	8435	339	-1864	-1524
18	6189	5890	7776	299	-1885	-1586
19	5563	5297	7189	265	-1891	-1626
20	5015	4779	6664	235	-1884	-1648

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 303 - LMSC STAGE & 1/2, 1970 IOC
SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS: LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS: LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS: PAYLOAD RDT&E	RECURRING COSTS: LAUNCH	RECURRING COSTS: PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	26	0	0	0	0	26
1973	396	0	0	0	0	396
1974	764	0	0	0	0	764
1975	917	10	28	0	0	955
1976	1207	25	90	0	0	322
1977	1207	25	411	78	252	1973
1978	1194	15	944	207	814	3174
1979	857	0	1049	317	975	3198
1980	416	0	1048	351	1128	2943
1981	287	0	1136	407	960	2790
1982	260	0	1089	413	1021	2783
1983	206	0	1104	486	1057	2853
1984	23	0	841	416	1195	2475
1985	0	0	558	505	1028	2091
1986	0	0	422	439	859	1720
1987	0	0	400	506	952	1858
1988	0	0	362	466	1033	1866
1989	0	0	241	498	989	1728
1990	0	0	66	446	419	931
TOTAL	7760	75	9789	5535	12687	35846

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 303 - LMSC STAGE & 1/2, 1970 IOC
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	314130	294674	223032	19456	71642	91098[1]
2	145181	136325	106836	8856	29488	38344
3	89864	84464	68491	5399	15972	21372
4	62809	59091	49535	3717	9555	13273
5	46971	44232	38293	2739	5939	8678
6	36684	34576	30881	2108	3695	5803
7	29531	27859	25642	1672	2216	3889
8	24311	22954	21751	1357	1202	2560
9	20361	19241	18752	1120	488	1608
10	17287	16349	16374	937	-25	1618
11	14841	14047	14445	793	-397	395
12	12858	12179	12850	678	-670	7
13	11226	10642	11512	583	-869	-286
14	9866	9360	10375	505	-1014	-508
15	8720	8279	9398	440	-1118	-677
16	7746	7360	8551	386	-1191	-804
17	6911	6571	7811	339	-1239	-900
18	6189	5890	7159	299	-1269	-970
19	5563	5297	6583	265	-1285	-1020
20	5015	4779	6070	235	-1290	-1054

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

1. Due to an inputting error, the present values shown here for the Shuttle are incorrect. The 10% NPV value has been adjusted and is correct.

LIFE CYCLE COST SUMMARY DATA
SCENARIO 304 - RATO I/II, 1979 FOC
SPACE SHUTTLE SYSTEM
(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	17	0	0	0	0	17
1973	230	0	0	0	0	230
1974	504	0	0	0	0	504
1975	746	10	28	0	0	784
1976	953	25	90	0	0	1068
1977	948	25	411	93	252	1729
1978	924	15	944	294	814	2991
1979	740	0	1049	358	975	3122
1980	631	0	1048	299	1128	3106
1981	466	0	1136	260	960	2822
1982	420	0	1089	279	1021	2809
1983	344	0	1104	269	1057	2774
1984	211	0	841	234	1195	2481
1985	127	0	558	315	1028	2028
1986	90	0	422	414	859	1785
1987	27	0	400	495	952	1874
1988	0	0	362	495	1038	1895
1989	0	0	241	495	989	1725
1990	0	0	66	495	419	980
TOTAL	7378	75	9789	4795	12687	34724

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 304 - RTO 1/11, 1979 FOC
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	279975	263375	185274	16600	78100	94700
2	131295	123600	90201	7695	33399	41094
3	82321	77553	58553	4768	18999	23768
4	58191	54859	42745	3331	12114	15445
5	43949	41463	33268	2486	8194	10681
6	34621	32685	26954	1935	5731	7666
7	28079	26528	22446	1551	4081	5632
8	23266	21996	19069	1269	2927	4196
9	19595	18539	16446	1056	2093	3149
10	16718	15828	14352	890	1475	2366
11	14413	13655	12644	758	1010	1768
12	12533	11882	11227	650	655	1306
13	10977	10414	10034	562	380	943
14	9674	9184	9017	489	167	656
15	8571	8143	8143	428	0	428
16	7629	7253	7384	376	-130	245
17	6819	6487	6721	331	-233	98
18	6117	5823	6138	293	-314	-20
19	5505	5245	5622	260	-377	-116
20	4970	4738	5163	232	-425	-193

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA
SCENARIO 305 - GRUMMAN TAHO, 1979 IOC
SPACE SHUTTLE SYSTEM
(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	62	0	0	0	0	62
1973	398	0	0	0	0	398
1974	757	0	0	0	0	757
1975	1108	10	28	0	0	1146
1976	1251	25	90	0	0	1366
1977	1080	25	411	78	252	1846
1978	801	15	944	207	814	2781
1979	611	0	1049	405	975	3040
1980	207	0	1048	478	1128	2861
1981	37	0	1136	572	960	2705
1982	15	0	1089	581	1021	2706
1983	0	0	1104	684	1057	2845
1984	0	0	841	589	1195	2625
1985	0	0	558	711	1028	2297
1986	0	0	422	615	859	1896
1987	0	0	400	712	952	2064
1988	0	0	362	655	1038	2055
1989	0	0	241	690	989	1920
1990	0	0	66	630	419	1115
TOTAL	6327	75	9789	7607	12687	36485

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 305 - GRUMMAN TAHO, 1979 IOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	314130	294674	237447	19456	57227	76683
2	145181	136325	112190	8856	24134	32990
3	89864	84464	71013	5399	13451	18850
4	62809	59091	50760	3717	8330	12048
5	46971	44232	38822	2739	5410	8149
6	36684	34576	31004	2108	3571	5679
7	29531	27859	25518	1672	2340	4012
8	24311	22954	21474	1357	1479	2836
9	20361	19241	18381	1120	859	1979
10	17287	16349	15947	937	402	1340
11	14841	14047	13986	793	60	854
12	12858	12179	12377	678	-197	480
13	11226	10642	11036	583	-393	189
14	9866	9360	9904	505	-543	-37
15	8720	8279	8937	440	-657	-216
16	7746	7360	8104	386	-744	-358
17	6911	6571	7380	339	-808	-469
18	6189	5890	6746	299	-856	-556
19	5563	5297	6188	265	-890	-624
20	5015	4779	5693	235	-913	-677

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 306 - GRUMMAN RS1C, 1979 FOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	314130	294674	210147	19456	84527	103983
2	145181	136325	100881	8856	35443	44299
3	89864	84464	64842	5399	19622	25021
4	62809	59091	47034	3717	12057	15774
5	46971	44232	36476	2739	7756	10495
6	36684	34576	29515	2108	5060	7168
7	29531	27859	24594	1672	3264	4936
8	24311	22954	20938	1357	2015	3373
9	20361	19241	18118	1120	1122	2243
10	17287	16349	15879	937	470	1408
11	14841	14047	14060	793	-13	780
12	12858	12179	12555	678	-375	302
13	11226	10642	11289	583	-647	-63
14	9866	9360	10212	505	-851	-345
15	8720	8279	9284	440	-1004	-564
16	7746	7360	8478	386	-1118	-732
17	6911	6571	7773	339	-1201	-861
18	6189	5890	7150	299	-1260	-960
19	5563	5297	6598	265	-1300	-1034
20	5015	4779	6105	235	-1325	-1089

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 307 - MCDC RATO, 1979 FOC

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	73	0	0	0	0	73
1973	467	0	0	0	0	467
1974	885	0	0	0	0	885
1975	1221	10	28	0	0	1259
1976	1424	25	90	0	0	1539
1977	1222	25	411	78	252	1988
1978	772	15	944	207	814	2752
1979	279	0	1049	405	975	2708
1980	158	0	1048	451	1128	2785
1981	37	0	1136	519	960	2652
1982	15	0	1089	526	1021	2651
1983	0	0	1104	608	1057	2769
1984	0	0	841	530	1195	2566
1985	0	0	558	630	1028	2216
1986	0	0	422	555	859	1836
1987	0	0	400	589	952	1941
1988	0	0	362	589	1038	1989
1989	0	0	241	608	989	1838
1990	0	0	66	342	419	827
TOTAL	6553	75	9789	6637	12687	35741

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 307 - MCDC RATO, 1979 FOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	314130	294674	230801	19456	63873	83329
2	145181	136325	109264	8856	27061	35917
3	89864	84464	69314	5399	15149	20549
4	62809	59091	49666	3717	9424	13142
5	46971	44232	38082	2739	6149	8888
6	36684	34576	30494	2108	4082	6190
7	29531	27859	25166	1672	2692	4365
8	24311	22954	21235	1357	1718	3075
9	20361	19241	18226	1120	1014	2134
10	17287	16349	15855	937	494	1432
11	14841	14047	13942	793	104	898
12	12858	12179	12371	678	-191	486
13	11226	10642	11059	583	-417	166
14	9866	9360	9950	505	-589	-83
15	8720	8279	9001	440	-722	-281
16	7746	7360	8182	386	-822	-436
17	6911	6571	7469	339	-898	-558
18	6189	5890	6844	299	-954	-654
19	5563	5297	6292	265	-995	-729
20	5015	4779	5803	235	-1023	-787

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA
SCENARIO 308 - MCDC IVC, 1979 FOC
SPACE SHUTTLE SYSTEM
(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	LAUNCH VEHICLE INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	62	0	0	0	0	62
1973	488	0	0	0	0	488
1974	1026	0	0	0	0	1026
1975	1521	10	28	0	0	1559
1976	1676	25	90	0	0	1791
1977	1354	25	411	78	252	2120
1978	1074	15	944	207	814	3054
1979	677	0	1049	376	975	3077
1980	296	0	1048	415	1128	2887
1981	37	0	1136	476	960	2609
1982	15	0	1089	482	1021	2607
1983	0	0	1104	559	1057	2720
1984	0	0	841	486	1195	2522
1985	0	0	558	579	1028	2165
1986	0	0	422	510	859	1791
1987	0	0	400	580	952	1932
1988	0	0	362	541	1038	1941
1989	0	0	241	570	989	1800
1990	0	0	66	517	419	1002
TOTAL	8226	75	9789	6376	12687	37153

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 308 - MCDC IVC, 1979 FOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	314130	294674	228788	19456	65886	85342
2	145181	136325	109148	8856	27176	36033
3	89864	84464	69742	5399	14721	20121
4	62809	59091	50310	3717	8781	12499
5	46971	44232	36817	2739	5415	8154
6	36684	34576	31262	2108	3314	5422
7	29531	27859	25938	1672	1920	3593
8	24311	22954	21995	1357	958	2315
9	20361	19241	18965	1120	275	1396
10	17287	16349	16567	937	-218	719
11	14841	14047	14627	793	-579	213
12	12858	12179	13026	678	-846	-168
13	11226	10642	11685	583	-1042	-458
14	9866	9360	10547	505	-1186	-680
15	8720	8279	9570	440	-1290	-849
16	7746	7360	8724	386	-1364	-978
17	6911	6571	7985	339	-1413	-1074
18	6189	5890	7335	299	-1445	-1145
19	5563	5297	6760	265	-1462	-1196
20	5015	4779	6247	235	-1467	-1231

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

8A.4 Table 8.4 Data

The data contained within this section represent the Life-Cycle Cost Summaries and Cost-Effectiveness analyses for the two-stage fully reusable shuttle and alternative configurations based upon Aerospace and contractor data. The data base excludes some of the DoD missions, and is predicated upon 514 shuttle flights over the 1979 to 1990 operating period.

SPACE PROGRAM COSTS
(1979-1990 OPERATIONS)

SCENARIO 400

NEW EXPENDABLE SYSTEM vs McDONNELL DOUGLAS RATO

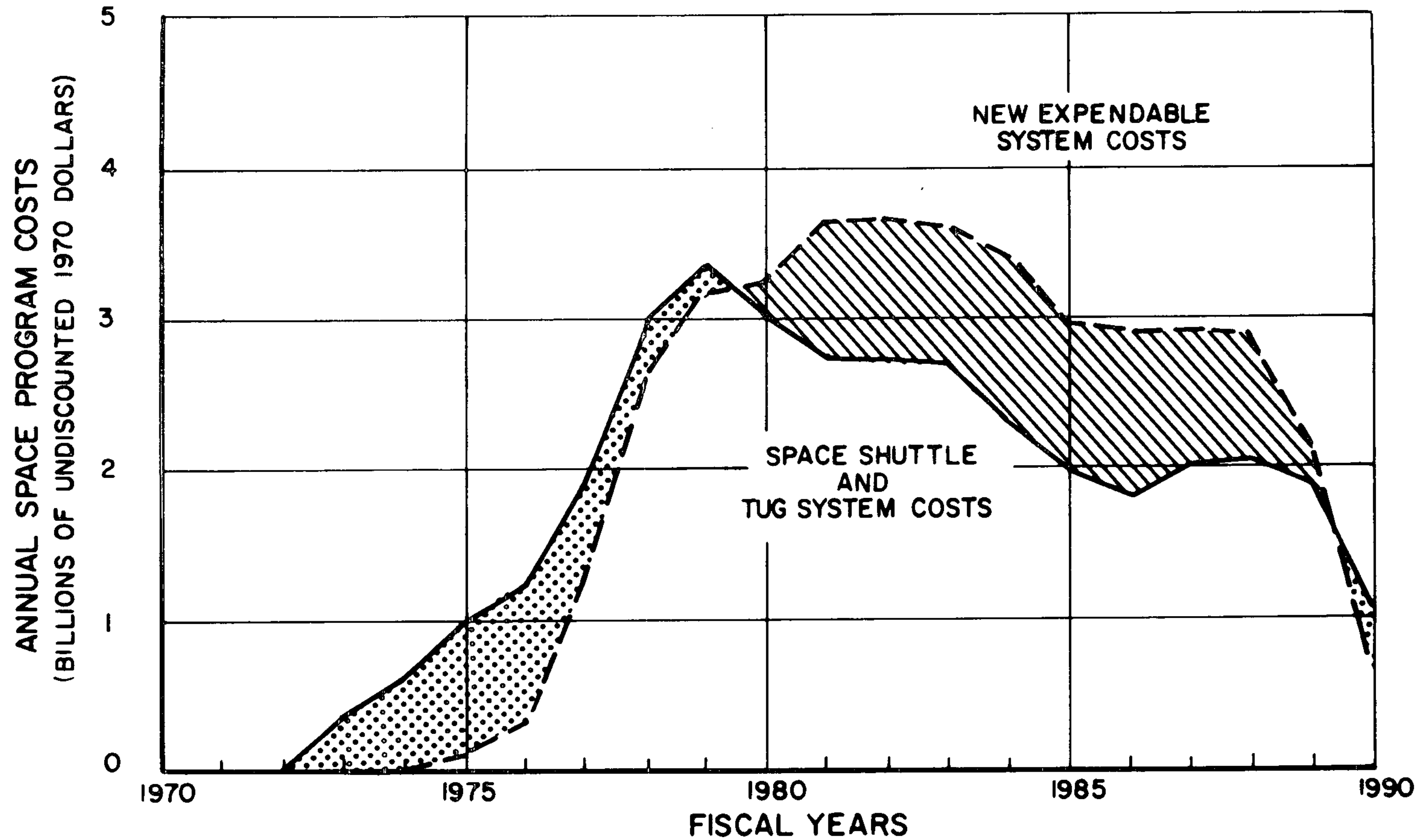

Figure 8A.4 Space Program Costs: New Expendable System Versus McDonnell Douglas RATO

LIFE CYCLE COST SUMMARY DATA
SCENARIO 400 - MCDC RATO, 1979 FOC
SPACE SHUTTLE SYSTEM
(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	24	0	0	0	0	24
1973	367	0	0	0	0	367
1974	708	0	0	0	0	708
1975	941	10	28	0	0	979
1976	1103	25	90	0	0	1218
1977	1099	25	411	93	252	1880
1978	1091	15	944	110	814	2974
1979	792	0	1049	517	975	3333
1980	385	0	1048	417	1128	2978
1981	266	0	1136	335	960	2697
1982	241	0	1089	357	1021	2708
1983	191	0	1104	318	1057	2670
1984	22	0	841	276	1195	2334
1985	0	0	558	392	1028	1978
1986	0	0	422	540	859	1821
1987	0	0	400	662	952	2014
1988	0	0	362	662	1038	2062
1989	0	0	241	662	989	1892
1990	0	0	66	662	419	1147
TOTAL	7230	75	9789	6003	12687	35784

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 400 - MCDC RATO, 1979 FOC
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	279975	263375	195638	16600	67736	84336
2	131295	123600	94907	7695	28692	36387
3	82321	77553	61444	4768	16108	20876
4	58191	54859	44773	3331	10086	13418
5	43949	41463	34805	2486	6658	9144
6	34621	32685	28181	1935	4503	6439
7	28079	26528	23466	1551	3061	4612
8	23266	21996	19941	1269	2054	3324
9	19595	18539	17210	1056	1328	2385
10	16718	15828	15034	890	794	1684
11	14413	13655	13262	758	393	1151
12	12533	11882	11792	650	89	740
13	10977	10414	10557	562	-142	420
14	9674	9184	9505	489	-320	169
15	8571	8143	8600	428	-457	-29
16	7629	7253	7816	376	-562	-186
17	6819	6487	7130	331	-642	-310
18	6117	5823	6526	293	-702	-409
19	5505	5245	5992	260	-747	-486
20	4970	4738	5517	232	-779	-547

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 401 GRUMMAN TAHO, 1979 FOC

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	21	0	0	0	0	21
1973	311	0	0	0	0	311
1974	603	0	0	0	0	603
1975	815	10	28	0	0	853
1976	973	25	90	0	0	1088
1977	971	25	411	93	252	1752
1978	967	15	944	114	814	2854
1979	701	0	1049	538	975	3263
1980	349	0	1048	445	1128	2970
1981	230	0	1136	363	960	2689
1982	205	0	1089	398	1021	2713
1983	161	0	1104	356	1057	2678
1984	19	0	841	304	1195	2359
1985	0	0	558	447	1028	2033
1986	0	0	422	627	859	1908
1987	0	0	400	775	952	2127
1988	0	0	362	775	1038	2175
1989	0	0	241	775	989	2005
1990	0	0	66	775	419	1260
TOTAL	6326	75	9789	6785	12687	35662

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 401 - GRUMMAN TAHO, 1979 FOC

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	279975	263375	201780	16600	61594	78194
2	131295	123600	97256	7695	26344	34039
3	82321	77553	62588	4768	14964	19733
4	58191	54859	45352	3331	9507	12838
5	43949	41463	35073	2486	6389	8876
6	34621	32685	28263	1935	4422	6357
7	28079	26528	23429	1551	3099	4650
8	23266	21996	19827	1269	2169	3439
9	19595	18539	17044	1056	1494	2551
10	16718	15828	14835	890	993	1883
11	14413	13655	13041	758	614	1372
12	12533	11882	11558	650	323	974
13	10977	10414	10315	562	99	662
14	9674	9184	9260	489	-75	414
15	8571	8143	8355	428	-212	215
16	7629	7253	7573	376	-319	56
17	6819	6487	6890	331	-403	-71
18	6117	5823	6292	293	-468	-174
19	5505	5245	5763	260	-518	-257
20	4970	4738	5294	232	-556	-324

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 402 - TAOS BEST CASE, 1979 FOC

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	21	0	0	0	0	21
1973	311	0	0	0	0	311
1974	603	0	0	0	0	603
1975	815	10	28	0	0	853
1976	973	25	90	0	0	1088
1977	971	25	411	93	252	1752
1978	967	15	944	110	814	2850
1979	701	0	1049	517	975	3242
1980	349	0	1048	417	1128	2942
1981	230	0	1136	335	960	2661
1982	205	0	1089	357	1021	2672
1983	161	0	1104	318	1057	2640
1984	20	0	841	276	1195	2332
1985	0	0	558	392	1028	1978
1986	0	0	422	540	859	1821
1987	0	0	400	662	952	2014
1988	0	0	362	662	1038	2062
1989	0	0	241	662	989	1892
1990	0	0	66	662	419	1147
TOTAL	6327	75	9789	6003	12687	34881

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 402 - TAOS BEST CASE 1979 FOC
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	279975	263375	194796	16600	68579	85179
2	131295	123600	94120	7695	29480	37175
3	82321	77553	60708	4768	16844	21613
4	58191	54859	44083	3331	10776	14108
5	43949	41463	34158	2486	7305	9791
6	34621	32685	27574	1935	5111	7046
7	28079	26528	22895	1551	3632	5183
8	23266	21996	19404	1269	2591	3861
9	19595	18539	16704	1056	1834	2891
10	16718	15828	14557	890	1271	2161
11	14413	13655	12811	758	843	1601
12	12533	11882	11367	650	515	1166
13	10977	10414	10154	562	260	823
14	9674	9184	9124	489	60	550
15	8571	8143	8239	428	-96	331
16	7629	7253	7473	376	-220	156
17	6819	6487	6805	331	-317	14
18	6117	5823	6218	293	-394	-100
19	5505	5245	5699	260	-454	-193
20	4970	4738	5238	232	-500	-268

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 403 - TAOS MIDDLE CASE, 1979 BOC 1979

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	23	0	0	0	0	23
1973	339	0	0	0	0	339
1974	656	0	0	0	0	656
1975	878	10	28	0	0	916
1976	1048	25	90	0	0	1163
1977	1040	25	411	93	252	1821
1978	1029	15	944	112	814	2914
1979	746	0	1049	527	975	3297
1980	367	0	1048	430	1128	2973
1981	248	0	1136	348	960	2692
1982	223	0	1089	376	1021	2709
1983	176	0	1104	336	1057	2673
1984	21	0	841	288	1195	2345
1985	0	0	558	417	1028	2003
1986	0	0	422	580	859	1861
1987	0	0	400	714	952	2066
1988	0	0	362	714	1038	2114
1989	0	0	241	714	989	1944
1990	0	0	66	714	419	1199
TOTAL	6794	75	9789	6363	12687	35708

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 403 - TAOS MIDDLE CASE, 1979 FOC , [illegible]
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	279975	263375	198365	16600	65009	81610
2	131295	123600	95934	7695	27666	35361
3	82321	77553	61932	4768	15620	20389
4	58191	54859	45009	3331	9850	13182
5	43949	41463	34903	2486	6559	9046
6	34621	32685	28197	1935	4487	6423
7	28079	26528	23430	1551	3098	4649
8	23266	21996	19872	1269	2124	3393
9	19595	18539	17119	1056	1420	2476
10	16718	15828	14928	890	899	1789
11	14413	13655	13147	758	507	1265
12	12533	11882	11673	650	209	860
13	10977	10414	10435	562	-20	542
14	9674	9184	9382	489	-197	291
15	8571	8143	8478	428	-335	92
16	7629	7253	7695	376	-442	-65
17	6819	6487	7011	331	-524	-192
18	6117	5823	6411	293	-587	-293
19	5505	5245	5880	260	-634	-374
20	4970	4738	5408	232	-670	-438

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA
SCENARIO 404 - TAOS WORST CASE, 1979 FOC
SPACE SHUTTLE SYSTEM
(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	24	0	0	0	0	24
1973	367	0	0	0	0	367
1974	708	0	0	0	0	708
1975	941	10	28	0	0	979
1976	1103	25	90	0	0	1218
1977	1099	25	411	93	252	1880
1978	1091	15	944	114	814	2978
1979	792	0	1049	538	975	3354
1980	385	0	1048	445	1128	3006
1981	266	0	1136	363	960	2725
1982	241	0	1089	398	1021	2749
1983	191	0	1104	356	1057	2708
1984	22	0	841	304	1195	2362
1985	0	0	558	447	1028	2033
1986	0	0	422	627	859	1908
1987	0	0	400	775	952	2127
1988	0	0	362	775	1038	2175
1989	0	0	241	775	989	2005
1990	0	0	66	775	419	1260
TOTAL	7230	75	9789	6785	12687	36566

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 404 - TAOS WORST CASE, 1979 FOC
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	279975	263375	202624	16600	60751	77351
2	131295	123600	98044	7695	25556	33251
3	82321	77553	63325	4768	14227	18996
4	58191	54859	46042	3331	8817	12148
5	43949	41463	35721	2486	5742	8228
6	34621	32685	28871	1935	3814	5749
7	28079	26528	24000	1551	2527	4078
8	23266	21996	20364	1269	1631	2901
9	19595	18539	17551	1056	988	2044
10	16718	15828	15312	890	515	1406
11	14413	13655	13491	758	163	921
12	12533	11882	11984	650	-101	549
13	10977	10414	10718	562	-303	259
14	9674	9184	9641	489	-456	32
15	8571	8143	8717	428	-573	-145
16	7629	7253	7915	376	-662	-285
17	6819	6487	7215	331	-728	-396
18	6117	5823	6600	293	-777	-483
19	5505	5245	6057	260	-811	-551
20	4970	4738	5573	232	-835	-603

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 405 - TWO-STAGE, FULLY REUSEABLE, CASE C

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	28	0	0	2382
1976	2307	25	90	0	0	2422
1977	1876	197	411	78	252	2814
1978	1033	555	944	207	814	3553
1979	315	1018	1049	333	975	3690
1980	0	829	1048	327	1128	3332
1981	0	410	1136	343	960	2849
1982	0	15	1089	346	1021	2471
1983	0	0	1104	388	1057	2549
1984	0	0	841	343	1195	2379
1985	0	0	558	398	1028	1984
1986	0	0	422	364	859	1645
1987	0	0	400	399	952	1751
1988	0	0	362	376	1038	1776
1989	0	0	241	405	989	1635
1990	0	0	66	362	419	847
TOTAL	11434	3059	9789	4669	12687	41638

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 405 - TWO-STAGE, FULLY REUSEABLE, CASE C
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	279975	263375	190940	16600	72434	89034
2	131295	123600	96202	7695	27398	35093
3	82321	77553	64488	4768	13064	17832
4	58191	54859	48522	3331	6337	9668
5	43949	41463	38855	2486	2607	5093
6	34621	32685	32340	1935	344	2280
7	28079	26528	27630	1551	-1102	448
8	23266	21996	24053	1269	-2056	-787
9	19595	18539	21235	1056	-2695	-1639
10	16718	15828	18952	890	-3124	-2233
11	14413	13655	17062	758	-3407	-2649
12	12533	11882	15470	650	-3587	-2936
13	10977	10414	14109	562	-3694	-3131
14	9674	9184	12931	489	-3747	-3257
15	8571	8143	11903	428	-3760	-3332
16	7629	7253	10998	376	-3745	-3368
17	6819	6487	10195	331	-3707	-3375
18	6117	5823	9478	293	-3654	-3361
19	5505	5245	8835	260	-3590	-3329
20	4970	4738	8255	232	-3517	-3285

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 406 - OSSA REDUCED TO 75 PERCENT (455 FLIGHTS)
SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS: LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS: LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS: PAYLOAD RDT&E	RECURRING COSTS: LAUNCH	RECURRING COSTS: PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	21	0	0	2375
1976	2307	25.	68	0	0	2400
1977	1876	197	339	70	225	2707
1978	1033	555	792	189	729	3298
1979	315	1018	863	314	880	3390
1980	0	829	850	314	1013	3006
1981	0	410	928	321	856	2515
1982	0	15	915	314	935	2179
1983	0	0	919	365	985	2269
1984	0	0	693	316	1100	2109
1985	0	0	444	373	944	1761
1986	0	0	333	336	804	1473
1987	0	0	310	369	871	1550
1988	0	0	281	346	938	1565
1989	0	0	195	373	899	1467
1990	0	0	55	331	380	766
TOTAL	11434	3059	8006	4331	11559	38389

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 406 - OSSA REDUCED TO 75 PERCENT (455 FLIGHTS)
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	251026	236249	170906	14776	65342	80119
2	117638	110800	86690	6837	24110	30947
3	73709	69480	58455	4229	11024	15254
4	52071	49122	44212	2949	4910	7859
5	39304	37107	35567	2197	1540	3737
6	30945	29238	29726	1707	-487	1219
7	25085	23720	25491	1365	-1771	-406
8	20775	19659	22266	1115	-2606	-1490
9	17490	16563	19719	926	-3155	-2228
10	14916	14136	17649	779	-3512	-2733
11	12855	12192	15932	662	-3739	-3077
12	11174	10606	14481	567	-3874	-3306
13	9784	9293	13237	490	-3943	-3453
14	8620	8194	12159	425	-3965	-3539
15	7635	7263	11216	371	-3952	-3581
16	6794	6468	10383	326	-3914	-3588
17	6071	5784	9643	286	-3858	-3571
18	5445	5191	8981	253	-3789	-3535
19	4900	4675	8385	224	-3710	-3485
20	4422	4222	7848	199	-3625	-3425

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 407 - OSSA REDUCED TO 50 PERCENT (400 FLIGHTS)

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	25	45	0	0	2377
1977	1876	197	267	63	198	2601
1978	1033	555	639	170	644	3041
1979	315	1018	676	295	785	3089
1980	0	829	653	302	897	2681
1981	0	410	720	300	751	2181
1982	0	15	740	281	848	1884
1983	0	0	733	341	913	1987
1984	0	0	545	289	1005	1839
1985	0	0	329	349	860	1538
1986	0	0	244	308	748	1300
1987	0	0	221	339	790	1350
1988	0	0	200	316	837	1353
1989	0	0	150	341	809	1300
1990	0	0	44	301	341	686
TOTAL	11434	3059	6220	3995	10426	35134

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 407 - OSSA REDUCED TO 50 PERCENT (400 FLIGHTS)
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	222076	209123	150873	12953	58250	71203
2	103980	98000	77178	5980	20822	26802
3	65098	61407	52422	3690	8985	12675
4	45951	43384	39901	2567	3483	6050
5	34659	32752	32278	1907	473	2381
6	27269	25790	27111	1478	-1320	158
7	22091	20911	23352	1179	-2441	-1261
8	18285	17323	20480	961	-3156	-2194
9	15385	14588	18203	796	-3614	-2817
10	13114	12445	16347	668	-3901	-3232
11	11296	10729	14801	567	-4072	-3505
12	9815	9330	13492	484	-4161	-3676
13	8590	8173	12366	417	-4193	-3775
14	7565	7204	11388	361	-4184	-3822
15	6699	6384	10529	315	-4145	-3829
16	5959	5683	9768	275	-4084	-3809
17	5323	5081	9091	242	-4009	-3767
18	4773	4560	8483	213	-3923	-3710
19	4294	4105	7936	188	-3830	-3642
20	3874	3707	7440	167	-3733	-3566

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 408 - 407 WITH DOD DOUBLED (507 FLIGHTS)

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS: LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS: LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS: PAYLOAD RDT&E	RECURRING COSTS: LAUNCH	RECURRING COSTS: PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	25	45	0	0	2377
1977	1876	197	352	87	294	2806
1978	1033	555	860	254	978	3680
1979	315	1018	824	403	1190	3750
1980	0	829	751	351	1398	3329
1981	0	410	854	336	1039	2639
1982	0	15	1015	329	1177	2536
1983	0	0	1032	410	1349	2791
1984	0	0	735	345	1461	2541
1985	0	0	369	412	1184	1965
1986	0	0	244	357	1043	1644
1987	0	0	221	405	1024	1650
1988	0	0	200	363	1062	1625
1989	0	0	150	388	1034	1572
1990	0	0	44	349	424	817
TOTAL	11434	3059	7710	4789	14657	41649

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 408 - 497 WITH DOD DOUBLED (507 FLIGHTS)
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	286944	269600	191825	17343	77775	95119
2	134210	126182	96580	8028	29602	37630
3	83948	78980	64711	4968	14268	19236
4	59212	55746	48675	3466	7070	10536
5	44632	42049	38970	2583	3078	5662
6	35095	33086	32432	2009	654	2663
7	28417	26809	27706	1608	-897	710
8	23510	22195	24118	1315	-1923	-607
9	19774	18680	21291	1093	-2611	-1517
10	16848	15927	19002	921	-3074	-2153
11	14507	13723	17107	783	-3383	-2599
12	12601	11928	15509	672	-3581	-2908
13	11025	10443	14144	581	-3701	-3119
14	9706	9200	12964	506	-3763	-3257
15	8591	8149	11933	442	-3784	-3341
16	7640	7251	11025	388	-3773	-3384
17	6822	6480	10219	342	-3739	-3396
18	6115	5811	9500	303	-3688	-3385
19	5499	5229	8855	269	-3625	-3355
20	4960	4720	8273	239	-3552	-3312

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 409 - 407 WITH DOD REDUCED TO 75 PERCENT (367 FLIGHTS)

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS PAYLOAD RDT&E	RECURRING COSTS LAUNCH	RECURRING COSTS PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	25	45	0	0	2377
1977	1876	197	245	57	174	2549
1978	1033	555	584	149	561	2882
1979	315	1018	639	268	684	2924
1980	0	829	628	289	772	2518
1981	0	410	687	291	679	2067
1982	0	15	671	269	766	1721
1983	0	0	658	324	804	1786
1984	0	0	497	275	891	1663
1985	0	0	319	333	779	1431
1986	0	0	244	295	674	1213
1987	0	0	221	322	732	1275
1988	0	0	200	304	781	1285
1989	0	0	150	329	752	1231
1990	0	0	44	289	320	653
TOTAL	11434	3059	5846	3794	9369	33502

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 409 - 407 WITH DOD REDUCED TO 75 PERCENT (367 Flights)
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	205860	194003	140634	11856	53368	65225
2	96423	90955	72327	5467	18627	24095
3	60385	57014	49349	3370	7664	11035
4	42636	40294	37707	2342	2586	4929
5	32166	30427	30605	1738	-177	1560
6	25312	23966	25781	1346	-1814	-468
7	20510	19437	22264	1072	-2826	-1754
8	16978	16105	19570	873	-3465	-2591
9	14288	13565	17430	722	-3865	-3142
10	12180	11575	15683	605	-4108	-3502
11	10493	9980	14225	512	-4244	-3731
12	9118	8680	12987	437	-4306	-3868
13	7982	7605	11921	376	-4316	-3939
14	7030	6704	10993	325	-4289	-3963
15	6226	5942	10177	283	-4235	-3951
16	5539	5292	9454	247	-4162	-3915
17	4948	4732	8809	216	-4077	-3860
18	4437	4247	8229	190	-3982	-3791
19	3992	3824	7706	168	-3882	-3714
20	3603	3454	7232	148	-3778	-3629

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 410 - DOD ADJUSTED FOR 624-FLIGHT MODEL

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	28	0	0	2382
1976	2307	25	90	0	0	2422
1977	1876	197	411	78	252	2814
1978	1033	555	944	207	814	3553
1979	315	1018	1049	283	975	3640
1980	0	829	1048	439	2781	5097
1981	0	410	1136	355	1450	3351
1982	0	15	1089	349	1383	2836
1983	0	0	1104	394	1406	2904
1984	0	0	841	344	1605	2790
1985	0	0	558	399	1287	2244
1986	0	0	422	368	1183	1973
1987	0	0	400	402	1139	1941
1988	0	0	362	378	1285	2025
1989	0	0	241	407	1236	1884
1990	0	0	66	365	510	941
TOTAL	11434	3059	9789	4768	17306	46356

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 410 - DOD ADJUSTED FOR 624-FLIGHT MODEL
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	373345	349189	255687	24156	93501	117658
2	172446	161441	124497	11005	36943	47948
3	106664	99949	81103	6714	18846	25560
4	74490	69864	59578	4625	10285	14911
5	55656	52246	46756	3409	5489	8899
6	43424	40799	38259	2625	2540	5165
7	34920	32836	32217	2083	619	2703
8	28715	27024	27700	1691	-676	1015
9	24022	22625	24195	1396	-1569	-173
10	20370	19201	21395	1169	-2193	-1024
11	17466	16476	19106	990	-2629	-1639
12	15113	14267	17199	846	-2932	-2086
13	13178	12449	15587	728	-3137	-2408
14	11566	10935	14206	631	-3271	-2639
15	10209	9659	13010	550	-3351	-2800
16	9056	8574	11965	482	-3391	-2909
17	3068	7644	11045	424	-3400	-2976
18	7216	6842	10229	374	-3387	-3012
19	6477	6145	9501	331	-3356	-3024
20	5831	5536	8848	295	-3311	-3016

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 411 - NON-NASA APPLICATIONS ADJUSTED FOR 624-FLIGHT MODEL

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

	NON-RECURRING COSTS			RECURRING COSTS		TOTAL
FISCAL YEAR	LAUNCH VEHICLE RDT&E	LAUNCH VEHICLE INVEST.	PAYLOAD RDT&E	LAUNCH	PAYLOAD	
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	28	0	0	2382
1976	2307	25	90	0	0	2422
1977	1876	197	411	78	252	2814
1978	1033	555	944	207	814	3553
1979	315	1018	1049	283	975	3640
1980	0	829	1048	355	1331	3563
1981	0	410	1136	346	1027	2919
1982	0	15	1089	346	1216	2666
1983	0	0	1104	393	1133	2630
1984	0	0	841	345	1417	2603
1985	0	0	558	402	1104	2064
1986	0	0	422	367	975	1764
1987	0	0	400	401	1052	1853
1988	0	0	362	378	1161	1901
1989	0	0	241	407	1051	1699
1990	0	0	66	364	461	891
TOTAL	11434	3059	9789	4672	13969	42923

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 411 - NON-NASA APPLICATIONS ADJUSTED FOR 624-FLIGHT MODEL
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	347230	320593	230055	26636	90537	117174
2	160273	148186	112621	12087	35564	47652
3	99071	91725	73725	7346	17999	25346
4	69148	64105	54399	5042	9706	14749
5	51638	47934	42864	3704	5069	8774
6	40271	37428	35203	2842	2225	5068
7	32372	30123	29744	2249	378	2627
8	26611	24791	25654	1820	-863	956
9	22255	20756	22473	1498	-1717	-218
10	18868	17617	19927	1251	-2310	-1058
11	16175	15118	17840	1056	-2722	-1665
12	13994	13093	16099	900	-3005	-2104
13	12201	11427	14623	773	-3195	-2421
14	10709	10039	13357	669	-3317	-2647
15	9452	8870	12258	582	-3387	-2805
16	8385	7876	11296	508	-3419	-2910
17	7471	7024	10447	446	-3422	-2975
18	6683	6289	9693	393	-3404	-3010
19	5999	5650	9019	348	-3368	-3020
20	5402	5093	8414	309	-3321	-3012

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 412 - 407 WITH NON-NASA APPLICATIONS INCREASED 50 PERCENT (446 FLIGHTS)

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS: LAUNCH VEHICLE RDT&E	NON-RECURRING COSTS: LAUNCH VEHICLE INVEST.	NON-RECURRING COSTS: PAYLOAD RDT&E	RECURRING COSTS: LAUNCH	RECURRING COSTS: PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	25	45	0	0	2377
1977	1876	197	280	74	221	2648
1978	1033	555	669	195	714	3166
1979	315	1018	696	308	859	3196
1980	0	829	677	328	965	2799
1981	0	410	739	333	793	2275
1982	0	15	755	291	887	1948
1983	0	0	752	375	960	2087
1984	0	0	574	302	1060	1936
1985	0	0	353	382	907	1642
1986	0	0	252	323	782	1357
1987	0	0	222	362	836	1420
1988	0	0	200	340	893	1433
1989	0	0	150	378	853	1381
1990	0	0	44	314	352	710
TOTAL	11434	3059	6422	4305	11082	36302

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 412 - 407 WITH NON-NASA APPLICATIONS INCREASED 50 PERCENT (446 FLIGHTS)
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	235640	220135	158014	15505	62121	77626
2	110341	103174	80570	7166	22603	29770
3	69085	64657	54574	4428	10082	14510
4	48770	45685	41439	3085	4245	7330
5	36788	34491	33452	2296	1039	3335
6	28945	27162	28044	1783	-882	901
7	23451	22025	24116	1426	-2091	-665
8	19411	18246	21118	1164	-2871	-1706
9	16333	15366	18744	967	-3377	-2410
10	13923	13109	16812	813	-3702	-2889
11	11993	11302	15205	691	-3903	-3211
12	10421	9828	13845	593	-4017	-3423
13	9121	8609	12678	512	-4068	-3556
14	8033	7588	11664	445	-4075	-3630
15	7113	6724	10774	388	-4050	-3661
16	6328	5987	9988	341	-4001	-3660
17	5653	5352	9289	300	-3936	-3635
18	5068	4803	8662	265	-3859	-3593
19	4560	4324	8097	235	-3773	-3537
20	4114	3904	7586	209	-3682	-3472

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 413 - 407 WITH NON-NASA APPLICATIONS DOUBLED (499 FLIGHTS)

SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	LAUNCH VEHICLE INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	25	45	0	0	2377
1977	1876	197	293	86	245	2697
1978	1033	555	698	219	784	3289
1979	315	1018	715	322	933	3303
1980	0	829	701	354	1032	2916
1981	0	410	757	366	835	2368
1982	0	15	769	301	926	2011
1983	0	0	771	409	1008	2188
1984	0	0	603	315	1116	2034
1985	0	0	376	416	955	1747
1986	0	0	261	339	816	1416
1987	0	0	223	386	881	1490
1988	0	0	200	363	949	1512
1989	0	0	150	415	897	1462
1990	0	0	44	327	362	733
TOTAL	11434	3059	6620	4618	11739	37470

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH
SCENARIO 413 -407 WITH NON-NASA APPLICATIONS DOUBLED (499 FLIGHTS)
(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	249204	231147	165155	18057	65991	84048
2	116701	108348	83963	8352	24385	32738
3	73073	67907	56727	5166	11179	16346
4	51588	47985	42978	3603	5007	8610
5	38916	36231	34626	2685	1604	4290
6	30622	28534	28978	2088	-444	1644
7	24810	23138	24880	1672	-1741	-69
8	20537	19169	21756	1368	-2586	-1218
9	17282	16144	19285	1137	-3141	-2003
10	14732	13773	17277	958	-3504	-2545
11	12691	11874	15609	816	-3734	-2918
12	11027	10326	14198	701	-3872	-3170
13	9652	9045	12989	606	-3943	-3336
14	8501	7973	11940	528	-3967	-3438
15	7527	7065	11020	462	-3955	-3492
16	6697	6290	10208	406	-3918	-3511
17	5982	5623	9486	359	-3863	-3503
18	5364	5046	8840	318	-3794	-3475
19	4826	4542	8258	283	-3715	-3432
20	4354	4102	7732	252	-3630	-3378

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

LIFE CYCLE COST SUMMARY DATA

SCENARIO 414 - 407 WITH NON-NASA APPLICATIONS TRIPLED (598 FLIGHTS)
SPACE SHUTTLE SYSTEM

(MILLIONS OF UNDISCOUNTED 1970 DOLLARS)

FISCAL YEAR	NON-RECURRING COSTS LAUNCH VEHICLE RDT&E	INVEST.	PAYLOAD RDT&E	RECURRING COSTS LAUNCH	PAYLOAD	TOTAL
1971	0	0	0	0	0	0
1972	294	0	0	0	0	294
1973	1206	0	0	0	0	1206
1974	2059	0	0	0	0	2059
1975	2344	10	14	0	0	2368
1976	2307	25	45	0	0	2377
1977	1876	197	319	109	292	2793
1978	1033	555	757	268	924	3537
1979	315	1018	754	349	1081	3517
1980	0	829	749	406	1167	3151
1981	0	410	794	432	919	2555
1982	0	15	798	321	1004	2138
1983	0	0	809	477	1103	2389
1984	0	0	661	341	1227	2229
1985	0	0	423	483	1050	1956
1986	0	0	278	370	884	1532
1987	0	0	225	433	972	1630
1988	0	0	200	410	1061	1671
1989	0	0	150	489	985	1624
1990	0	0	44	353	383	780
TOTAL	11434	3059	7020	5241	13052	39806

COST EFFECTIVENESS ANALYSIS - EQUAL CAPABILITY APPROACH

SCENARIO 414 - 407 WITH NON-NASA APPLICATIONS TRIPLED (598 FLIGHTS)

(TOTAL PROGRAM COST IN MILLIONS OF DISCOUNTED 1970 DOLLARS)

DISCOUNT	1970 PRESENT VALUES			COST DIFFERENCES		
RATE	CE	NE	SH	CE-NE	NE-SH	CE-SH
1	276331	253170	179437	23160	73733	96893
2	129422	118697	90748	10725	27948	38674
3	81049	74406	61032	6643	13373	20016
4	57226	52586	46055	4639	6531	11171
5	43174	39710	36974	3463	2735	6199
6	33975	31277	30845	2697	432	3130
7	27529	25365	26407	2164	-1042	1122
8	22790	21016	23032	1774	-2015	-241
9	19179	17700	20368	1478	-2668	-1189
10	16350	15101	18208	1248	-3106	-1857
11	14086	13020	16417	1065	-3397	-2331
12	12240	11322	14905	917	-3583	-2665
13	10714	9918	13612	796	-3693	-2897
14	9437	8742	12492	694	-3750	-3055
15	8356	7746	11512	609	-3765	-3156
16	7434	6896	10649	537	-3752	-3214
17	6641	6165	9882	476	-3716	-3240
18	5955	5532	9196	423	-3664	-3241
19	5357	4980	8580	377	-3600	-3222
20	4834	4496	8025	337	-3528	-3190

NOTES - - CE=CURRENT EXPENDABLE, NE=NEW EXPENDABLE, SH=SPACE SHUTTLE SYSTEM

GPO 930-320